THE BIOLOGY AND FISHERY OF A MARINE PERCOID FISH,

PSAMMOPERCA WAIGIENSIS (CUVIER) FROM THE

PALK BAY AND GULF OF MANNAR.

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January, 1968

THE BIOLOGY AND FISHERY OF A MARINE PERCOID FISH,

PSAMMOPERCA WAIGIENSIS (CUVIER)

FROM THE PALK BAY AND GULF OF MANNAR.

A Thesis

submitted to

THE UNIVERSITY OF BOMBAY

for the degree of

D O C T O R O F P H I L O S O P H Y

in

Z O O L O G Y

By

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Statement showing in what particulars my work is based on the discovery of new facts by me or of new relations of facts observed by others and how the work tends to the general advancement of knowledge (vide O.413).

Life history information, especially details regarding age and growth, spawning, fecundity, food habits and mortality, is extremely important in fishery management, which is the application of such scientific knowledge concerning fish populations to problems of obtaining the maximum production from a fishery. Such a knowledge has been lacking for the principal species comprising the commercial percoid catches of the Palk Bay and Gulf of Mannar. Psammoperca waigiensis (Cuvier), one such common perch contributing to a fairly good sustenance fishery in these areas, was selected for investigation. From the studies thus undertaken, useful information on the biology of this fish and interesting results having a practical bearing on its fishery have been obtained. As such, the present work is considered the first comprehensive study of the typical perch.

The fish is omnivorous but subsists mainly on crabs and prawns. It has a maximum life-span of at least four years and it attains a maximum size of about 37.0 cm. The growth rate has been found to be fastest

during the first year of its life. It attains maturity at the end of the first year and spawns almost throughout the year, except perhaps, during the months of May and June. This observation differs from the view expressed by Prabhu (1956) that the fish spawns in July - August and January - February.

A morphometric study of fish from the Palk Bay and Gulf of Mannar suggests that four characters, viz., snout, headlength, snout to pelvic fin and back depth could possibly be utilised for critical racial studies.

The one-year-old fish contribute to the greater part of the catches at almost all places where a good fishery exists. The fishery being dependant on adults and confined to a limited area of the inshore regions, most fish that are caught are expected to have spawned at least once, thereby leaving enough spawners to replenish the stock for the maintenance of the commercial fishery at its present level. Thus, the problem of depleting the stock by exploitation does not appear to arise. Since the species appears to be short-lived, it is considered rational to exploit it further, without detriment to the fish stock.

(M. Vasudev Pai)

Statement indicating the sources from which my information has been derived and the extent to which I have based my work on the work of others, and the portion or portions of my thesis which I claim as original (vide O.413).

The thesis embodies the results of my investigations on the biology and fishery of Psammoperca waigiensis (Cuvier), the common perch of the Palk Bay and Gulf of Mannar, carried out during the period from 1954 to 1958, at the Central Marine Fisheries Research Institute, as a Research Scholar. The data included in the thesis were collected by me from the Palk Bay and Gulf of Mannar. The investigations were conducted entirely by me and the thesis is original in its entirety.

(M. Vasudev Pai)

PREFACE

Marine fisheries in India are of a varied nature. Most of the important fisheries are conducted in the coastal waters by numerous small indigenous craft and gear. One such important gear used along the coasts of Palk Bay and Gulf of Mannar is the trap, known as 'Koodu' in Tamil which has been described by Prabhu (1954). The composition of trap catches includes the perch, Psammoperca waigiensis (Cuvier) locally known as 'Senganni'. This species supports a sustenance fishery at some places along the coasts of Palk Bay and Gulf of Mannar. Although a common perch of commercial importance, only very little information is at present available on the biology and fishery of this species. In order to provide such information to the maximum extent, a comprehensive study was initiated and the results spread over a period of four years from 1954 to 1958, form the basis of the present thesis.

Based on this study, it is inferred that this species breeds almost throughout the year. A maximum life-span of at least four years is indicated and the species attains a maximum size of about 37.0 cm. The growth rate is found to be fastest during the first year of its life. The species attains maturity at the end of first year and is found to be omnivorous, mainly subsisting on crabs and prawns. The one-year-old fish contribute to the greater part of the catches at almost all places where a good fishery exists. The fishery being dependant on adults and confined to a limited area of the inshore regions,

most fish that are caught are expected to have spawned at least once, thereby leaving enough spawners to replenish the stock in future for the maintenance of the commercial fishery at its present level. The morphometric study of fish from the Palk Bay and Gulf of Mannar suggests that four characters, viz., snout, head length, snout to pelvic fin and back depth could possibly be utilised for critical racial studies. A study of the relative growth of body parts indicates that snout to anal fin and snout to second dorsal fin grow at a faster rate than other characters.

I wish to record my deep sense of gratitude and thanks to Dr. N.K. Panikkar, the then Chief Research Officer, Central Marine Fisheries Research Station, for suggesting this problem and for the guidance and constant encouragement during the course of this work. I am also deeply grateful to Dr. S. Jones, Director, Central Marine Fisheries Research Institute, for the guidance, constructive criticism and unfailing encouragement during the latter part of this work. My sincere thanks are specially due to Dr. R.R. Prasad, Deputy Director and Dr. R.V. Nair, Senior Research Officer, Central Marine Fisheries Research Institute for many valuable suggestions and help in the presentation of the thesis. The statistical treatment of the data was done under the guidance and supervision of Mr. S.K. Banerji, Senior Research Officer, Central Marine Fisheries Research Institute, to whom I owe my deep sense of gratitude. I also owe my thanks to Dr. E.G. Silas, Research Officer of this Institute for specially going through the chapter on 'Systematics

and Distribution'. My thanks are due to Dr. P.S.B.R. James, Assistant Research Officer of this Institute for suggesting improvements. It is my privilege to thank many of my other colleagues of this Institute who have been helpful to me in many ways during the course of this investigation.

I am thankful to the Ministry of Education, Government of India for awarding a Junior Research Scholarship during the earlier part of this investigation and later a Senior Research Scholarship during the tenure of which this investigation was completed.

Central Marine Fisheries
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M. VASUDEV PAI

Dated:

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INTRODUCTION

Perches constitute an important group of food fishes along the coasts of peninsular India; more so, along the coasts of Palk Bay and Gulf of Mannar, where they form as much as 50 per cent of the total annual catch. The shallow waters of these areas abound in dense growth of algae, sea grass and corals forming a good niche for the carnivorous perches, as they take shelter in the nooks and crannies and snap at the prey such as the crustaceans, juvenile of teleostean fishes, molluscs, etc. The percentage composition of perches landed in India during the period 1950-1964 ranged from a maximum of 4.44 (in 1950) to a minimum of 0.57 (in 1951).

Biology of quite a few Indian perches has been worked out so far. Job (1940) gave a detailed account of the nutrition of the Madras perches. Menon (1948) studied the food of the 'bekti', Lates calcarifer from Bengal. Chacko (1949) gave an account of the food of some perches from the Gulf of Mannar. Prabhu (1954) gave a detailed account of the perch fishery in the area around Mandapam and recorded Psammoperca waigiensis from the trap landings. Prabhu (1956) also studied the diameter frequency of intra-ovarian eggs and indicated that the species spawns twice a year, viz., July-August and January-February. Some mention is made of the fishery for P. waigiensis in the Madras Fisheries Administration Reports (1931-32) wherein it is stated, "Rains during the last two years have destroyed the sea weeds and resuscitated the shell-beds to a large extent. Although with this change,

the important 'Sengani' (Psammoperca waigiensis) fishery disappeared, 'Pothi keluru' (Arius leptetocephalus) abounded and as much as 270 maunds was brought to the yard for curing". Apart from the above very few references to this species, there is no other work pertaining to many other aspects of its biology from Indian waters. It is needless to say, that for a proper management and rational exploitation of any fisheries, a thorough knowledge of the biology and fishery of the species constituting the resource is essential. In this context, a comprehensive study of the biology of P. waigiensis was not hitherto attempted and, hence, a detailed study of the biology and fishery of this perch has been undertaken.

The thesis embodying the findings of the investigations thus undertaken comprises of nine chapters. The details of the material used and methods = followed are given in 'Material and Methods'. The meteorological, hydrographic and oceanographic conditions characteristic of the areas covered by the investigation are described under 'Description of the Environment'.

The systematics and distribution are dealt with in Chapter 1. Systematics comprises of synonymy, diagnosis and nomenclatorial discussion. The general distribution of the species in different geographical areas is given. The variability of the species in various areas is discussed.

Chapter 2 deals with the reproduction of the species. Maturity stages are described and the development of ova to maturity studied. Size at maturity, spawning season and frequency of spawning are indicated. Other aspects discussed include rate of growth of gonads, fecundity, relation between length of fish, weight of fish and weight of ovary, and sex ratio.

In Chapter 3 are included studies on age and growth. The results of the analysis of the length-frequency data and inferences based on the study of the otoliths are detailed. The von Bertalanffy growth equation, as applied to describe the growth of this fish, is given.

The food and feeding habits of the species are discussed in detail in Chapter 4. The results of the qualitative and quantitative analysis of stomach contents are given. Other aspects of the study such as feeding intensity, food in relation to size, and correlation between the stomach contents and their occurrence in the environment are presented.

Chapters 5 and 6 deal with length-weight relationship and relative condition factor, and total length-standard length relationship respectively.

In Chapter 7 are given the results of morphometric study of fish from the Palk Bay and Gulf of Mannar; also included are results of studies on relative growth of body parts.

Chapter 8 deals with fishing seasons and gear used in the fishery at the various fishing hamlets, and catch data. Types of gear used in the fishery and modes of their operation are described. The catch data presented comprise of average annual landings and percentage composition of P. waigiensis.

The age-group composition of the commercial catches at various centres is discussed in Chapter 9; the total mortality coefficients between different age-groups are also presented and discussed.

Tables are inserted at appropriate places in the text. Illustrations are given wherever necessary. The references relating to the biological work are listed at the end of the thesis.

MATERIAL AND METHODS

The material for the study was drawn mainly from four centres (vide Map, Fig. 1), viz., Vedalai (Lat. 9° 15' 45" N; Long. 79° 06' 15" E), Munakkad (Lat. 9° 17' 30" N; Long. 79° 08' E), Devipatnam (Lat. 9° 28' 51" N; Long. 78° 54' E) and Tondi (Lat. 9° 45' 09" N; Long. 79° 01' 09" E). Traps ('Koodu') and shore seines ('Olai Valai') account for the landings at Vedalai and Munakkad. At Devipatnam, hooks & lines ('Thoondi'), gill nets ('Kannikka Valai' or 'Senganni Valai') and shore seines ('Olai Valai' and 'Karai Valai') are operated in the fishery. At Tondi, shore seines ('Olai Valai') and gill nets ('Kannikka Valai') are used in the fishery. Occasionally, samples were collected from Rameswaram (Lat. 9° 17' 42"N; Long. 79° 19' 30" E) and Kilakkarai (Lat. 9° 14' 09" N; Long. 78° 46' 44" E), where traps and shore seines account for the catches.

Vedalai and Munakkad were visited twice or thrice a week for recording the total length measurements and selecting a representative sample for analysis in the laboratory. Four trips were made to Devipatnam every month and when the collections could not be made at the landing place, the day's catch was examined in the Ramnad market. As Tondi is still farther away, one trip lasting three days was made every month.

As the fish has a rounded caudal fin, the

Fig. 1. Map showing the localities covered during the investigation.

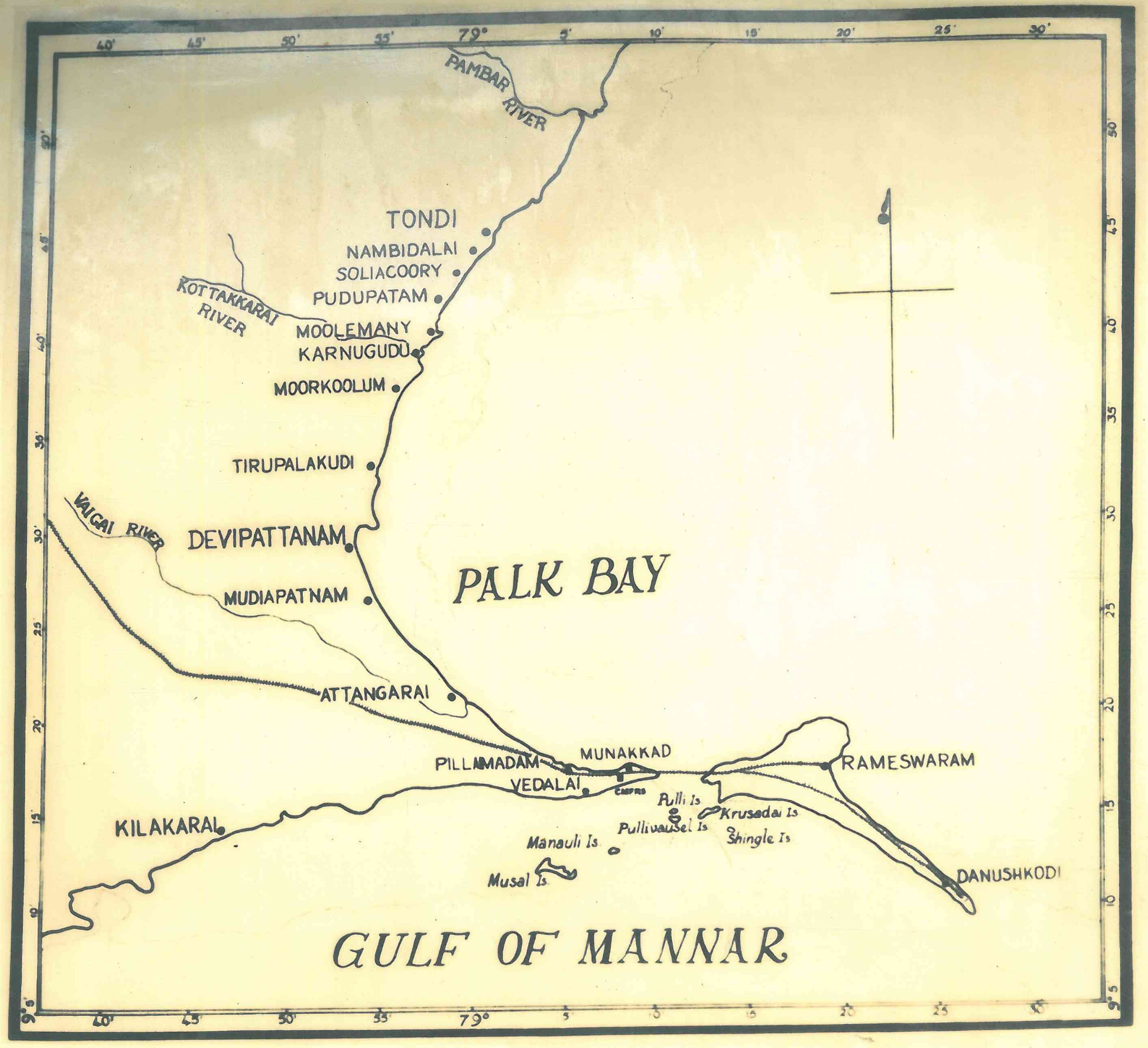
PAMBAR RIVER
TONDI
NAMBIDALAI
SOLIACOORY
PUDUPATAM
KOTTAKKARAI RIVER
MOOLEMANY
KARNUGUDU
MOORKOOLUM
TIRUPALAKUDI
VAIGAI RIVER
DEVIPATTANAM
MUDIAPATNAM
PALK BAY
ATTANGARAI
PILLAIMADAM
MUNAKKAD
VEDALAI
RAMESWARAM
KILAKARAI
Pulli Is
Krusadai Is
Pullivaasel Is
Shingle Is
Manauli Is
Musal Is
DANUSHKODI
GULF OF MANNAR
79°

Fig. 1

total length was measured from the tip of the snout to the tip of the longest median caudal ray (Ricker and Merriman, 1945) and the standard length was measured likewise, from the tip of the snout to the last scale in the lateral line. The latter measurement was taken in the laboratory while the former was taken at the landing place only. The measurements were taken to the nearest millimetre. The size of the representative sample varied from 15 to 20 fish and these were taken in such a way that all the size-groups in the day's catch were represented. On the day of visit, all details such as the depth at which the fishing operations were carried out, number of traps or nets operated, types of bait used (in the case of traps and hooks & lines), number of men engaged in the fishery, duration of fishing and certain meteorological conditions were noted.

The sample of 15 to 20 fish taken to the laboratory was analysed immediately for various details such as maturity, condition of feed and growth checks on otoliths and scales. The total length and standard length of each fish were recorded first and then the fish was weighed after sponging out water and any adhering matter by means of dry cloth. The weight was recorded to the nearest gramme. The fish was then cut open from the ventral side and the size of the gonads and the degree of fullness of the stomach were noted.

In the case of the ovaries, stages of

maturity have been described based on their macroscopic appearance and a microscopic study of the intraovarian eggs. As regards the testes, only their relative size and appearance are of any use in this respect. The intra-ovarian eggs were teased out from ovaries preserved in 5% formalin and measured with the help of an ocular micro-meter eyepiece. The gonads were weighed in the fresh condition on a sensitive balance to the nearest milli-gramme. In determining the number of ova in each ovary, weighed portions of ripe ovaries were teased in water and only the large fully transparent ova were enumerated by naked eye. The total number in the paired ovaries from which the sample had been taken was estimated by multi-plying the number counted in the sample by the ratio of the weight of the whole ovary to the weight of the sample.

The stomachs were preserved in 5% formalin and were examined later in the laboratory. As soon as the stomachs were removed from the body cavity and pre-served, details such as length of the fish, sex and matu-rity were noted. Fish captured by the traps were not utilised for the study of the food of the species, as invariably the bait items such as holothurians and crushed crabs dominated in the stomachs. The 'Points Method' of Swynnerton and Worthington (1940), as modified by Frost (1943), has been adopted in the analysis of stomach con-tents. Stomachs of 1069 fish belonging to various size-groups were analysed from the four centres-Vedalai,

Munakkad, Devipatnam and Tondi and the number of stomachs analysed from the respective centres are 221, 184, 381 and 283.

Otoliths and scales have been examined for growth studies. The otoliths were extricated by making a median dorsal incision in the cranium by means of a scalpel. The otoliths were then cleaned in water, dried and preserved. Otoliths from preserved fish were not utilised for examination, as formalin was found to affect the clarity of rings in the otoliths. While grinding otoliths on carborundum, special care was taken to grind the convex side first and then the concave side. This process of alternate grinding of the convex and concave sides was continued till the otolith was reduced to a thin flake, as this gave the best results. Otoliths studied in the present investigation were drawn from the same samples brought to the laboratory for the study of the other aspects of the biology of the species. Ground otoliths were examined in xylol with reflected light at a known magnification for the determination of the number of rings, R the total radius of the otolith and r the radius of the otolith up to the outer border of each of the rings.

Scales from the axilla were examined for growth checks. Scale samples were collected from fresh specimens, cleaned and then mounted dry between glass slides, held in position by means of adhesive tape. The scale mounts were also examined under reflected light.

Data for this investigation have been collected over a period of four years, from 1954 to 1958. Samples were, however, not available during some months due to adverse weather conditions or cessation of fishing*. Random samples of fish were drawn from the commercial landings for recording the total length measurements. A total of 27,382 fish, ranging in total length from 3.8 cm. to 37.0 cm., were measured for the length - frequency study from the four centres; the number of fish drawn from Vedalai, Munakkad, Devipatnam and Tondi are 7048, 4815, 13470 and 2049 respectively. Length-frequency data have been analysed month-wise for the four centres separately. Fish have been grouped at 1 cm. class interval, e.g., 5-6 cm., 6-7 cm., etc. Fish measuring 5.1 cm. to 6.0 cm. have been included in the 5-6 cm. size-group. The same procedure has been uniformly adopted.

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* A few samples were also collected subsequent to 1958, from 1963 to 1965 during visits to Vedalai, Munakkad, Devipatnam and Tondi. These have been treated as checks to the data collected from 1954 to 1958. Such corroboratory observations are also incorporated.

DESCRIPTION OF THE ENVIRONMENT

As already stated, the material was collected from the vicinity of the Central Marine Fisheries Research Institute which is situated on a small peninsular extension of the east coast of South India, in line with the Rameswaram Island (vide Map, Fig. 1). The Palk Bay is situated in the north and the Gulf of Mannar in the south of the peninsula and the island; the waters of the two are in communication with each other through the Pamban Pass (Lat. 9° 17' N; Long. 79° 12' E) and also through the "Adam's Bridge" between Danushkodi and Talaimannar on the west coast of Ceylon.

Though the area is exposed both to the South West and North East monsoons, the rainfall during the former is negligible. Most of the annual rainfall of about 760 mm. falls during the North East monsoon months, November-January. During the South West monsoon, the waters in the Gulf of Mannar become turbulent owing to strong winds. This condition generally continues up to August. The drift of the water in this area is from south to north during April to August (period of the South West monsoon and turbulence) and is particularly strong through the Pamban Pass reaching sometimes velocity of 5-6 knots. At this time, the waters of the Palk Bay are calm. With the onset of the North East monsoon, i.e., from September onwards, the direction of the drift is reversed. During this period, comparatively calm conditions prevail in the Gulf, and the

waters of the Palk Bay become turbulent.

The fishing operations are profoundly influenced by these conditions in the Palk Bay and Gulf of Mannar; fishing during the South West monsoon period, May-August is carried out in the Palk Bay which is calm and during the North East monsoon period, September onwards, the operations are conducted in the Gulf of Mannar (vide Chapter 8, Fishing seasons, gear and catch data).

Even up to a distance of about 16 km. from the shore, the depth does not exceed 11-13 metres both in the Palk Bay and Gulf of Mannar. The Palk Bay has a much larger shallow area than the Gulf of Mannar. The Gulf of Mannar is more open as compared to the Palk Bay, which is a more or less land-locked sea (Admiralty chart 68 a*).The inshore region of the Gulf of Mannar is full of rocky patches with intervening areas of sand and mud, while that of the Palk Bay is mostly muddy. Dredge collections made in the Gulf of Mannar and Palk Bay (vide Chapter 4, Food and feeding habits - v correlation between the stomach contents and their occurrence in the environment) reveal that the flora of the bottom in the former comprised of almost the same forms as those in the latter. Angiosperms, red algae, brown algae and green algae were found in both the habitats. The fauna associated with the flora in both the habitats were also found to be fairly evenly distributed. At distances ranging from 5-10 km. from the mainland of the Gulf of

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*India-South East Coast - Palk Strait and Gulf of Mannar. Published at the Admiralty, New Edition, 1950.

Mannar, there is a chain of islands situated almost parallel to the coast. These islands are mainly of coral origin probably of the nature of fringing reefs. The waters between these islands and the mainland are more shallow than those outside. The islands are separated from each other by broad gaps of water which establish continuity between the shallow and deeper portions of the sea.

The Gulf of Mannar being wide open, its waters are subject to considerable influences from adjacent seas. Sewell (1929) has given the data on the surface currents of waters around the peninsula of India. According to him, a current commencing from the head of the Bay of Bengal flows towards the south west during September-November, sweeps along the east coast of India until it finally reaches the east coast of Ceylon, then bends westwards, keeping close along the coast and enters the Gulf of Mannar. A current from the west coast also enters the Gulf at the same time. There is a perceptible change in the direction of the surface currents during the subsequent three months, December-February. The current from the west coast no longer enters the Gulf; a current which sweeps across the Bay of Bengal, strikes the Coromandel Coast, gets deflected and moves down south along the east coast of Ceylon and enters the Gulf of Mannar before it moves further west. During March-May, waters from the Arabian Sea and probably also from the Indian Ocean enter the Gulf and the turbulent conditions in the Gulf, associated with

the South West monsoon, begin to prevail during this period. The period June-August, represents the greater part of the South West monsoon. Sewell (op. cit.) has not indicated any surface current entering the Gulf of Mannar during this period. It has been observed by later workers that there is a drift from south to north and it is probable that water masses from the Indian Ocean and Arabian Sea enter the Gulf. The presence of high salinity low silicate surface waters and the appearence of such open ocean forms as Janthina roseola, Velella sp., Porpita pacifica and Physalia utriculus, indicate the possible incursion of oceanic surface waters into the coastal regions of the area during June-August.

Prasad (1954 b) has given an account of the variations in surface temperature of the seawater in the Gulf of Mannar and Palk Bay. The fluctuations in the surface temperature in the Gulf show a double oscillation in the course of a year. The temperature is at a minimum in January and it rises steadily until it reaches the maximum in April. From May onwards, it shows a decline which may be due to strong winds causing a high rate of evaporation. There is a subsequent increase in the surface temperature, though the rise is not comparable to that of April, during August-October, the exact month varying from year to year. This period marks the end of the South West monsoon. The slight increase in the surface temperature may be due to the cessation of the strong wind and consequent reduction in the rate of evaporation. There is a second fall in the temperature,

concomitant with the onset of the North East monsoon, when the sun is at its maximum southern declination. The surface temperature of the waters of the Palk Bay is of a slightly lower order than that of the Gulf of Mannar.

Jayaraman (1954) has described the seasonal variations in salinity, dissolved oxygen and nutrient salts in the inshore waters of the Gulf of Mannar and Palk Bay near Mandapam. With the additional data collected subsequently (Prasad, 1958), it would appear that there are noticeable differences in the hydrological conditions of the water masses of these regions. In the Gulf of Mannar, the salinity of the surface waters is consistently higher from January-September and in December, but it is practically the same in the two regions in October-November. The dissolved oxygen in the surface waters of the Gulf of Mannar is almost always higher, owing propably to greater coral reef formation in this region. Silicates are invariably lower in the Gulf of Mannar, possibly because of greater land drainage into the Palk Bay and more oceanic nature of the waters of the Gulf. Nutrient salts such as phosphate and nitrate show variations in the two regions - the former is slightly higher in the Gulf of Mannar during many months and the latter is often lower. The lower concentration of nitrate in the coastal waters of the Gulf of Mannar may be due to higher population of denitri-

fying bacteria (Velankar, 1955).

Planktological investigations in the inshore waters of the Gulf of Manner and Palk Bay (Prasad, 1954 a, 1954 b and 1956) have thrown considerable light on the fact that though the two water masses are contiguous, the production and characteristics of plankton of the two regions show significant differences. The zooplankton of the two regions does not exhibit the same degree of difference as the phytoplankton population as regards average annual production, which is slightly more (about 9 per cent) in the Palk Bay than in the Gulf of Mannar.

Although, the total plankton production is lower in the inshore waters of the Gulf of Mannar, a consideration of the total biomass of the two regions suggests that it may be actually greater in the Gulf. Further, it would appear that the waters of the Gulf of Mannar are richer in their content of nutrient salts (with the potentiality to produce a greater biomass) than those of the Palk Bay, since it is believed that a tongue of the Antarctic bottom water, rich in nutrients strikes the south end of Ceylon and upwells in the Gulf of Manner (Sewell, 1932).

CHAPTER I

SYSTEMATICS AND DISTRIBUTION

The genus Psammoperca was erected by Richardson (1848) with Psammoperca datnioides as the type species. Bleeker (1853) placed the species, Labrax waigiensis Cuvier (in Cuvier and Valenciennes, 1828) under the genus Psammoperca Richardson and designated the species as Psammoperca waigiensis.

The genus Labrax according to Cuvier (1828) includes seven species, Labrax lupus Cuvier being the type species (Gill, 1860). The remaining six species were assigned to separate genera (Gill, 1860). Though Cuvier (1828) was the first to distinguish the genus, as remarked by Gill (1860), its type had been long previously placed by Klein (1749) as the first of two species constituting a group for which he used the same name Labrax.

Distinguishing characters of the genus Labrax Cuvier and the genus Psammoperca Richardson are given below:

Character	Labrax Cuvier	Psammoperca Richardson
Teeth on jaws, vomer and palatines	Villiform	Crowded, rounded and granular
Tongue	Small oval disc of teeth at the base	Smooth
Number of spines on the operculum	Two	One

In the nature of teeth on jaws, vomer and palatines, the present observations on Psammoperca are in agreement with those of Richardson (1848). Richardson's description of the tongue shows disagreement with the observations of Cuvier (1828) and Bleeker (1851). The latter asserted that there is an oblong patch of teeth at the base of the tongue, "lingua basi thurma denticulorum oblonga scabra." As stated by Cuvier (1828) and Bleeker (1851), a small patch of teeth is present in the posterior part of the tongue. Both Richardson (1848) and Bleeker (1851) noticed a single spine on the operculum and a strong horozontal spine at the angle of the preoperculum above which the margin was pectinated. Cuvier (1828) also reported one spine on the operculum and a fairly strong single spine on the preoperculum of L. waigiensis (although one of the generic characters assigned to Labrax by Cuvier (1828) is the presence of two spines on the operculum). Present observations are in agreement with those of the above mentioned authors.

Genus Psammoperca Richardson, 1848

Labrax (partim) Cuvier, in Cuvier and Valenciennes, 1828, Histoire Naturelle des Poissons, 2: 55, Type species, Labrax lupus Cuvier (Type locality: Mediterranean Sea).

Psammoperca Richardson, 1848, Ichthyology of the voyage of H.M.S. Erebus & Terror, 115-116, Haplotype, Psammoperca datnioides Richardson [=Labrax waigiensis Cuvier] (Type locality: Australia).

Cnidon Müller and Troschel, 1849, Horae Ichth., 3:21, Orthotype, Cnidon chinensis Müller and Troschel [=Labrax waigiensis Cuvier] (Type locality: Manila).

*Hypopterus Gill, 1861, Proc. Acad. nat. Sci. Philad., 13: 50-51, Orthotype, Hypopterus macropterus Gill [=Psammoperca macroptera Günther] (Type locality: Victoria=Port Essington, Northern Territory, at mouth of Victoria River, Australia).

Diagnosis

Branchiostegals seven; teeth on vomer and palatines crowded and granular; canines absent; tongue with a small oval disc of teeth posteriorly; two dorsals, continuous, basal scaly sheath; first dorsal with 7 spines and second with one spine and 12 rays; anal with 3 spines and 8 rays; caudal rounded; operculum with a small, and preoperculum with a strong spine; posterior border of latter serrated and lower border entire; scales rather large, ctenoid, number in longitudinal row varying from 46 to 50.

General distribution

Ceylon, India, Malaysia, Singapore, Indonesia, Philippines, China, Formosa, Japan and Australia.

Psammoperca waigiensis (Cuvier)

Labrax waigiensis Cuvier, in Cuvier and Valenciennes, 1828, Histoire Naturelle des Poissons, 2: 83-84 (Type locality: Waigiou).

Lesson, 1830, Voy. Coquille Zool., 2(1):237 (Offack Bay, Waigiou).

Bleeker, 1851, Natuurk. Tijdschr. Ned.-Indie, 2:478 (Rio, Malay Archipelago).

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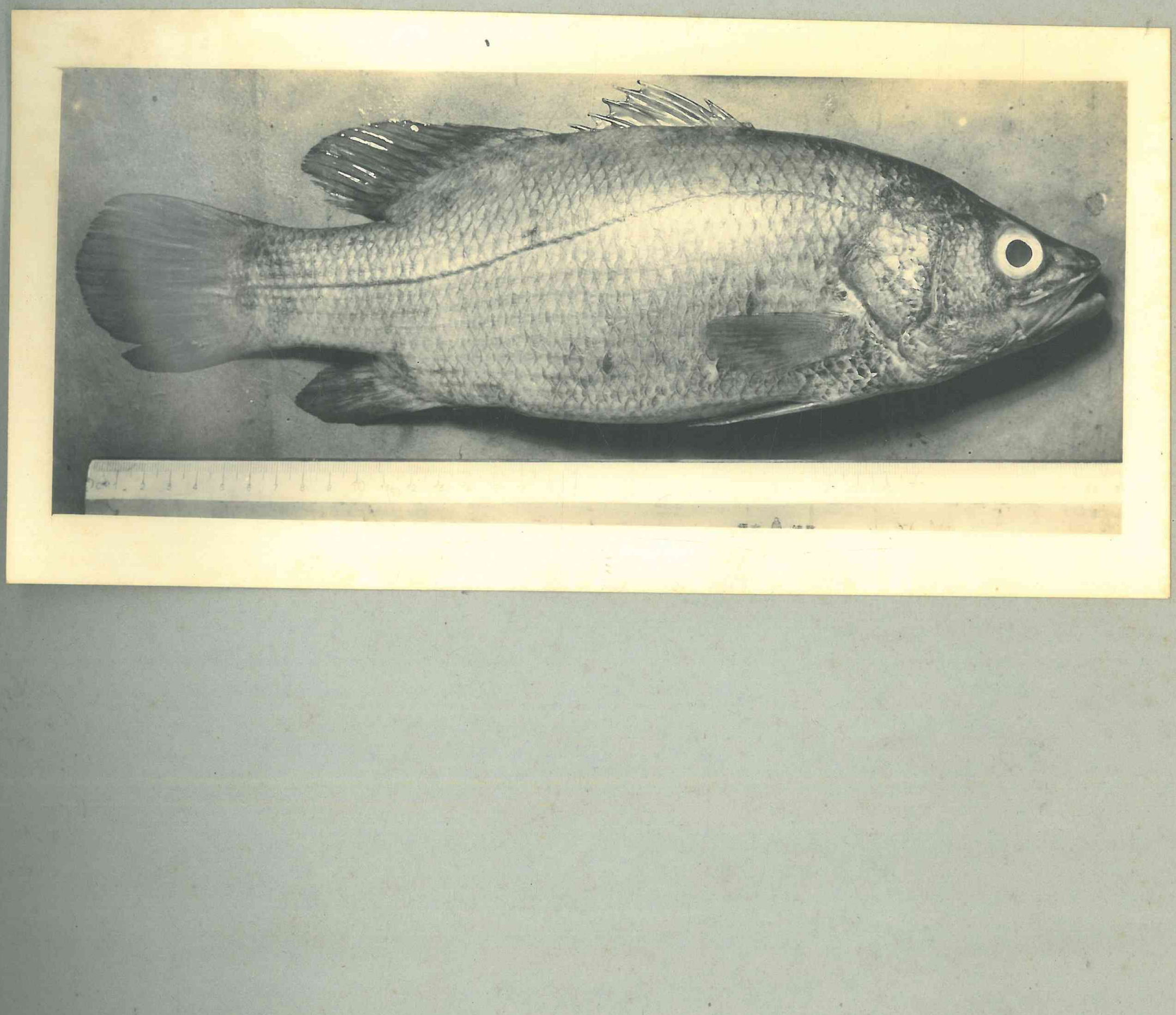
* Doubtful synonym

Psammoperca waigiensis (Cuvier)

(Female: total length - 37.0 cm.)



Gill, 1860, Proc. Acad. nat. Sci. Philad.,
108-109 (Locality: not known).

Psammoperca datnioides Richardson, 1848, Ichthyology of the voyage of H.M.S. Erebus & Terror,
116-117, pl.57, figs. 1-2
(Type locality: Australia).

Cnidon chinensis Müller and Troschel, 1849, Horae Ichth., 3:21
(Type locality: Manila).

Meyer, 1885, An. Soc. esp. Hist. nat., Madrid,
14: 8 (North Celebes, Manila Bay, Cebu).

Psammoperca waigiensis Bleeker, 1853, Natuurk. Tijdschr. Ned.-Indie, 5:177 (Type locality: Banka).

Günther, 1859, Catalogue of the Acanthopterygian Fishes in the collection of the British

Gill, 1861, Proc. Acad. nat. Sci. Philad.,
13:50 (after Bleeker).

Kner, 1865, Reise Novara, Expedition-Zool.,
1(5):13 (Hongkong and Manila).

Günther, 1872, Ann. Mag. nat. Hist., 10:426
(Victoria, Australia, New South Wales, Torres Straits, Manila, China).

Bleeker, 1876, Atlas Ichthyologique des Indes Orientales Neerlandaises, 7:108, pl.(28)
306, fig. 2 (Singapore, Bintang, Bangka, Java, Madura, Borneo, Celebes, Waigiu, Manila).

Klunzinger, 1879, Sber. Akad. Wiss. Wien., 80(1):
343 (Endeavour River, Queensland).

Macleay, 1880, Proc. Linn. Soc. N.S.W., 5:307 (North Australia).

Macleay, 1881, Descriptive catalogue of Australian Fishes, 1:307 - 308 (North Australia).

Day, 1889, Fauna of British India, 1:440 (Madras).

Kent, 1893, Great Barrier Reef, 281, 369 (Queensland).

Weber, 1895, Semon's Zool. Forsch. Reis., Australia, 5:622 (Thursday Island, Queensland).

Jordan and Evermann, 1903, Proc. U.S. nat. Mus., 25:340 (Formosa).

Pellegrin, 1905, Bull. Soc. zool. Fr., 30:83 (d'Along Bay, Tonkin).

Evermann and Seale, 1906, Bull. Bur. Fish. Wash., 26:78 (Bulan).

Seale, 1910, Philipp. J. Sci., 5(4): 275 (Borneo, Philippines).

McCulloch, 1912, Rec. West. Aust. Mus., 1(2):215 (Geraldton).

Weber, 1913, Siboga Expedition., Fische, 57: 215 (Makassar, Tual, Pepela Bay, Rotti).

Fowler, 1918, Copeia, 58:63 (Philippines).

Tanaka, 1922, Figures and Descriptions of the Fishes of Japan, 32:602, pl.147, fig. 407 (Kochi).

Fowler, 1927, Proc. Acad. nat. Sci., Philad., 275 (Philippines).

Fowler, 1928, Mem. Bernice P. Bishop Mus., 10:171 (Locality: not known).

Weber and de Beaufort, 1929, The fishes of the Indo-Australian Archipelago, 5:394 (Madras to China, Philippines, North Australia).

Fowler and Bean, 1930, Bull. U.S. nat. Mus., 10:179-181 (Philippines).

Herre, 1933, J.pan - Pacif. Res. Instn., 8:4 (Sandakan, British North Borneo), 8(Dumaguete, Negros Oriental Province).

Herre, 1934, Fishes 1931 Philippine Exped., 43(Manila, Luzon, Culion, Sitankai, Sulu Province).

Fowler, 1938, A list of fishes known from Malaya, 138 (Singapore).

Herre, 1953, Res. Rep. U.S. Fish. Wildl. Serv., 20:242-244 (Philippines).

Ogilby, 1954, The commercial fishes and fisheries of Queensland, 43-45 (Queensland).

Prabhu, 1954, Indian J. Fish., 1:94-129 (Mandapam - Palk Bay and Gulf of Mannar).

Munro, 1955, The marine and freshwater fishes of Ceylon, 106 (Ceylon).

Prabhu, 1956, Indian J. Fish., 3(1):59-90 (Mandapam - Palk Bay and Gulf of Mannar).

Marshall, 1964, Fishes of the Great Barrier Reef and coastal waters of Queensland, 146 (Queensland).

Whitley, 1964, Proc. Linn. Soc. N.S.W., 89(1): 44 (Australia).

Psammoperca vaigiensis Boulenger, 1895, Catalogue of the Paciform Fishes in the British Museum, 1:365 [nom. emend. from Bleeker] (Victoria River, Australia, Hammond Island, Cebu, China Sea, Borneo, Singapore, Madras, Ceylon).

Düncker, 1903, Mitt. naturh. Mus. Hamb., 21:147 (after Boulenger).

Maxwell, 1921, J. Straits Brch. R. Asiat. Soc., 84:268 (Locality: not known).

Material

203 specimens ranging in size 7.0 cm. to 27.0 cm. from Munakkad (Palk Bay) and Vedalai (Gulf of Mannar).

Description

B.7; D_1.VII; D_2.I,12; A.III,8; P.2,14-15; V.I,5; L.l.46-50; L.tr.5½/1/11-12.

Body sub-elongate, dorsal profile slightly arched, somewhat concave before eyes. Height 2.6-4.8, 3.1-5.5 in total length. Head 2.5-3.6, 3.1-4.0 in total length. Eye 3.8-5.7, snout 2.8-6.2 and inter-orbital space 3.6-7.0 in head. Nostrils far distant. Mouth moderate, protractile and slightly oblique.

Jaws equal. Maxillary exposed, reaching posterior border of pupil, the width of its distal extremity one-half or nearly two-thirds of eye. Small crowded granular teeth in rows in jaws and palatines; triangular patch on vomer. Tongue with small patch of teeth posteriorly. Lower gill rakers 11-13. Preorbital smooth. Preopercle with hind edge finely serrated, smooth inferiorly; a strong spine at angle. Opercle ends in spine. Snout naked. Cheeks with about 15 rows of scales, the lower series smaller than the upper ones. Scales from occiput extending forward to between eyes. Opercle with large scales. Fin bases broadly with fine scales. First dorsal spine small, half length of second, which is almost equal to eye. Third spine somewhat shorter than half length of head, slightly longer than fourth one, which is as strong as the third one. Spine of second dorsal equal to sixth spine of first dorsal. Base of second dorsal rounded, as long as that of first dorsal; the longest soft rays nearly as long as third spine of first dorsal. First anal spine nearly two-thirds of the length of the second (which is nearly as long as the third one) and equal to the diameter of eye. Anal rounded, its origin below middle of second dorsal, its end a little farther back than that of second dorsal. Pectorals shorter than ventrals, somewhat less than post-orbital part of head. Ventral spine about as long as snout. Caudal rounded. Least height of caudal peduncle equal to its length and slightly less than post-orbital part of head. Scales ctenoid. Vertebrae 25. Colour of fresh specimens reddish brown in the upper half of body and sides, with silvery white reflections in the lower region. Eyes reddish brown with golden hues up to about an hour after capture (hence the name

'Senganni' in Tamil language which means red eye); later they turn pale white. Fins reddish brown. Ventrals more blackish in their distal part. Colour of preserved specimens reddish brown.

Distribution

Along the Indian Coast, the species has been reported from the Coromandel Coast (from Point Calimere up to Pulicat Lake, about 100 km. north of Madras) and the coasts of Palk Bay and Gulf of Mannar. It has not been observed by the author, nor so far reported from the west coast of India and other localities along the east coast.

Remarks

Cuvier (1828) reported 7 branchiostegals, 7 spines in the first dorsal fin and one spine and 13 rays in the second dorsal, 3 spines and 9 rays in the anal, 17 rays in the caudal, 16 rays in the pectoral and one spine and 5 rays in the ventral fin of L. waigiensis. Lesson (1830) and Bleeker (1851) described L. waigiensis from Waigiou and Malay Archipelago respectively. While there is agreement among the above authors as regards the dorsal, caudal, ventral and anal fin counts, the pectoral fin count (2/15) given by Bleeker (1851) differed from the count (16) of Cuvier (1828) and Lesson (1830). The dorsal fin count of 8 spines given by Richardson (1848) for P. datnioides is noteworthy.

Müller and Troschel (1849) described Cnidon chinensis as a new species under the new genus Cnidon. Günther (1872) in

his amended diagnosis of the genus Psammoperca Richardson, has synonymised Cnidon with Psammoperca, the latter having priority. Meyer (1885) mentioned Cnidon chinensis as synonymous to Psammoperca waigiensis after Günther (1872).

Günther (1859) gave the dorsal fin count as 8/ 1 / 12-13 , but in 1872 in the amended diagnosis of the genus Psammoperca, he remarked that "What I have formerly (in dried specimens) taken for the spine of the second dorsal fin is, in fact, only the hardened first simple ray." Therefore, the revised fin formula, according to him, would be 7/ 1 / 13-14 .

Gill (1860) while commenting on the seven species of Labrax of Cuvier (1828, 1829) referred to Bleeker's synonymising Labrax waigiensis Cuvier with Psammoperca datnioides Richardson (=Psammoperca waigiensis) and drew attention to the discrepancies in the description of the species by Cuvier (1828), Richardson (1848) and Bleeker (1851).

Details of meristic counts and Variations in some important body proportions of P. waigiensis based on the present study are given in the next page.

Meristic counts of P. waigiensis

No. of specimens	Branchiostegals	First dorsal	Second dorsal	Anal	Pectoral		Ventral
Variations	7	VII	I,12	III,8	2,14	2,15	I,5
203	203	203	203	203	155	48	203

Continued

L.l					L.tr.		Gill rakers		
46	47	48	49	50	5½/1/11	5½/1/12	11	12	13
42	10	46	21	84	184	19	148	15	40

Body proportions of P. waigiensis in thousandths of total length.

No. of specimens	Characters	Range	Mean
203	Standard length	810-940	878
,,	Head length	249-325	288
,,	Maximum depth of body	181-324	243
,,	Eye diameter	48- 80	64
,,	Inter-orbital distance	39- 76	51
,,	Snout	48-105	76

A comparison of the morphometric and meristic data of P. waigiensis given by Boulenger (1895, specific locality not given), Tanaka (1922) from Japan, Weber and de Beaufort (1929) from the Indo-Australian Archipelage region, Fowler and Bean (1930) from Philippines, Munro (1955) from Ceylon, Marshall (1964) from the Great Barrier Reef and the present observations from the Palk Bay and Gulf of Mannar indicate almost consistent meristic counts except for the variation in anal rays mentioned by Boulenger (1895) and Tanaka (1922) which are 9 and 8-9 respectively. Although the size of the specimens examined by all the above mentioned authors is large (28.9-35.0 cm.), except that of Fowler and Bean (1930, 13.7-35.5 cm.) and the present author (7.0-27.0 cm.), there is general agreement in the important body proportions. There is close similarity in the proportion of head in standard length in specimens from all the regions but the eye in specimens from Japan is smaller ($6\frac{2}{3}$ in head) and consequently the snout is larger than eye and its proportion small in head when compared to that of the fish from the rest of the localities mentioned above. Comparatively, the proportion of height in standard length shows a greater range of variation (2.6-4.8 in standard length) in the Indian material than elsewhere, which may, however, be dependent on the total size range of the fish examined. As to the colour of the species, the descriptions of Tanaka (1922) and Marshall (1964) differ from those of the others including the present author (who agree in most respects), in that they mention the presence of longitudinal lines on the sides of the body.

All the other authors, who have referred to

P. waigiensis, have given brief descriptions of the species mostly based on earlier works or reported its occurrence in certain localities. Except for some minor variations in body proportions, all the authors basically agree as to the typical characters of the species, as also found in the present author's observations. Although several authors have reported or described P. waigiensis from a number of localities in its entire range of distribution, it is significant that the characteristic red eye colour of the species in all sizes in live or fresh condition up to about an hour after capture has not been mentioned by them, presumably because they had access to preserved material only.

Günther (1859) described a new species, Psammoperca macroptera based on a single specimen collected from Victoria (=Port Essington, Northern Territory) at mouth of Victoria River, Australia.

A brief description of the species after Günther (1859) is given below:

D_1.VIII; D_2.I, 13; A.III, 13.

Height of the body one-third of the total length. Preorbital and suborbital arch strongly serrated. Length of head 4 2/5 in the total; inter-orbital distance one-sixth of the length of head, more than half the diameter of eye. Snout equals in length diameter of eye which is one-fourth of the length of head. Snout laterally covered by the preorbital, which widends above and furnished by strong spinous teeth beneath, directed backwards; serrature becomes finer on the suborbital arch. Upper maxillary styliform and forms posteriorly a tri-

angular plate; it does not appear to reach the middle of the eye. Operculum has a somewhat rounded posterior angle, without distinct point. Preoperculum finely serrated along the posterior limb and armed with a triangular and keeled spine of moderate size at the angle; lower limb smooth.

Greatest depth of the body is between the origins of second dorsal fin and anal. Tail, without caudal, as high as long. Third spine of dorsal fin very long, one-sixth of the total length; first spine small; second shorter than half of third; fourth, fifth and sixth rapidly decrease in length; seventh and eighth short, inserted between both dorsals. First spine of second dorsal little longer, half the height of the fin; rays nearly equal in length, much shorter than the spinous part and form a rounded fin. Caudal rounded with eighteen rays. Anal fin resembles in shape the soft dorsal, its base longer and the longest ray somewhat higher; spines of moderate strength, second rather longer than third and two-thirds the length of the longest ray. Pectoral and ventral fins nearly equal in length, the latter not reaching the vent; their spine equals fifth spine of dorsal fin.

Gill (1861) erected the genus Hypopterus with Hypopterus macropterus (=Psammoperca macroptera Günther) as the type species. He gave the generic characters of Hypopterus (based on Günther's description of P. macroptera) as follows:

"Body ovate and compressed. Head conical in profile. Preoperculum serrated behind, entire below, and armed at its angle

with a large horizontal spine. Operculum with its posterior angle subrotundate. Suborbital bones serrated. Anterior dorsal with eight spines, the third of which is elongated. Anal fin longer than the second dorsal, and furnished with three spines and about thirteen rays.".

Bleeker (1876) referred to P. macroptera in some detail. According to him, his specimens show a constant count of 7 spines in the first dorsal, whereas Günther (1859) stated it to be 8. The lateral line scale count was stated by Bleeker (1876) never to exceed 45 which, however, was not given by Günther (1859). In addition to Günther's report of P. macroptera from Australia, Bleeker (1876) reported its distribution to extend outward of "l'Inde archipélagique, jusqu' aux côtes de Chine et de la Nouvelle-Hollande méridionale" and also at Manila. Macleay (1881) in his "Descriptive catalogue of Australian Fishes" briefly described P. macroptera, probably after Günther (1859). Boulenger (1895) reporting on a specimen 140 mm. in total length stated that the first dorsal fin consists of 7 spines and the second dorsal one spine and 15 rays, the latter count (15) differing from that of Günther (1859). Fowler and Bean (1930) considered the genus Hypopterus synonymous to Psammoperca. Whitley (1964) in his account entitled "A Survey of Australian Ichthyology - Name-list of the fishes recorded from Australia" recorded (without description) Hypopterus macropterus (Günther) as distinct (No.1084 in the list) from P. waigiensis (No.1083), presumably after Gill (1861). Apparently, Psammoperca and Hypopterus are not considered congeneric, and according to him, Hypopterus macropterus (Günther) is valid. However, as no material was available to the present author, it is difficult to comment further on this species.

CHAPTER 2

REPRODUCTION

i. Structure of gonads

The ovary in P. waigiensis, as in many teleostean fishes, is of the cystovarian type. It is bilobed and the two lobes are separate and of equal size. The testis, like the ovary, is bilobed and the lobes are of equal size.

ii. Maturity stages and ova diamter studies

Maturity stages

The stages of maturity have been classified based on the macroscopic appearance of the gonads and a microscopic study of the intra-ovarian eggs. It has been found convenient to classify them into seven stages, corresponding to the stages defined by the International Council for the Exploration of the Sea (Lovern and Wood, 1937), the details of which are given in Table I. The same classification applies to both the sexes.

Ova diameter studies

It is well known that fishes exhibit definite spawning periodicities. Based on the principle that the spawning period is short and definite when the batch of transparent yolkless ova destined to mature and be spawned are withdrawn in a single group and are sharply distinguished from the general egg-stock and that the spawning period is long and indefinite when there is no such differentiation between the batch of maturing ova and the general egg-stock, maturation

TABLE I

Classification of maturity stages in P. waigiensis

Maturity stage	Macroscopic appearance	Microscopic appearance and size of ova
I - Immature	Ovaries slender and transparent - ova not visible to naked eye. Testes slender and whitish.	Minute transparent ova measuring up to 0.234 mm.
II- Developing immatures and recovering spents	Ovaries enlarged and amber coloured - ova small, not visible to naked eye. Testes enlarged and whitish.	Ova small, transparent and unyolked measuring from 0.234 mm. to 0.350 mm.; mode at 0.277 mm.
III- Maturing	Ovaries greatly enlarged, slightly yellowish in appearance - ova visible to naked eye. Testes well enlarged and pale white.	Maturing ova, wherein yolk deposition has commenced but not complete, measuring from 0.350 mm. to 0.438 mm.; mode at 0.365 mm.
IV- Mature	Ovaries greatly enlarged, yellowish in appearance and have profuse venation - large opaque ova present. Testes greatly enlarged and milky-white.	Mature opaque ova, fully laden with yolk, measuring from 0.438 mm. to 0.555 mm.; modes at 0.453 mm. and 0.511 mm.
V- Advanced mature	Ovaries greatly enlarged, dark yellow in appearance and have profuse venation - large opaque ova present. Testes greatly enlarged, convoluted in appearance and milky-white.	Mature opaque ova, fully laden with yolk, transparent at the periphery, measuring from 0.555mm. to 0.672 mm.; mode at 0.628 mm.
VI- Ripe	Ovaries greatly enlarged speckled in appearance and have large transparent ova - spawning in progress or just imminent. Testes greatly enlarged, convoluted in appearance and milky-white - exude milt on application of slight pressure.	Ripe transparent ova measuring above 0.672 mm. diameter, each having a single oil globule; mode at 0.803 mm. Diameter of oil globules ranged from 0.192 mm. to 0.250 mm.; ova not perfectly spherical and devoid of chromatophores; yolk unsegmented; oil globules transparent and colourless.
VII- Spent	Spent ovaries, shrunk and with large residual ova in the lumen; otherwise, give the appearance of ovaries in Stage II.	Few large residual transparent ova ranging in diameter from 0.584 mm. to 0.730 mm.; mode at 0.657 mm.

being a continuous process, many workers have determined the spawning periodicities of fishes by taking diameter measurements of ova from ripe ovaries or those in penultimate stage of ripeness (Clark, 1925, 1934; Hickling and Rutenberg, 1936; De Jong, 1940; Karandikar and Palekar, 1950; Palekar and Karandikar, 1952, 1953; Prabhu, 1955, 1956; Sarojini, 1957, 1958; Pillay, 1958; Dharmamba, 1959; Karekar and Bal, 1960).

For ova diameter studies, fishes were collected in the fresh condition and the ovaries removed and preserved in 5% formalin. These ovaries in various stages of maturity have been used for taking the ova diameter measurements. The method used by Clark (1934) has been followed. The diameter measurements of 1000 ova from each ovary were taken by means of an eye-piece micrometer, fitted in a compound microscope, at a known magnification. Ova less than 0.117 mm. in diameter were not measured, since they were present in large numbers in the ovaries at all stages of maturity.

In order to find the type of distribution of the ova in an ovary, an ovary in Stage IV maturity from a fish measuring 21.6 cm. total length has been taken and the ova diameter frequency of a sample of 1000 ova taken from the central portion of the right lobe is plotted in the form of a polygon (Fig.2). The polygon indicates three different groups of eggs, viz., the immature group with modes at 0.248 mm. and 0.307 mm., the maturing group with a mode at 0.394 mm., and the mature group with modes at 0.453 mm. and 0.511 mm. Measurements of ova

Fig. 2. Ova diameter frequency polygon of P. waigiensis in Stage IV maturity.

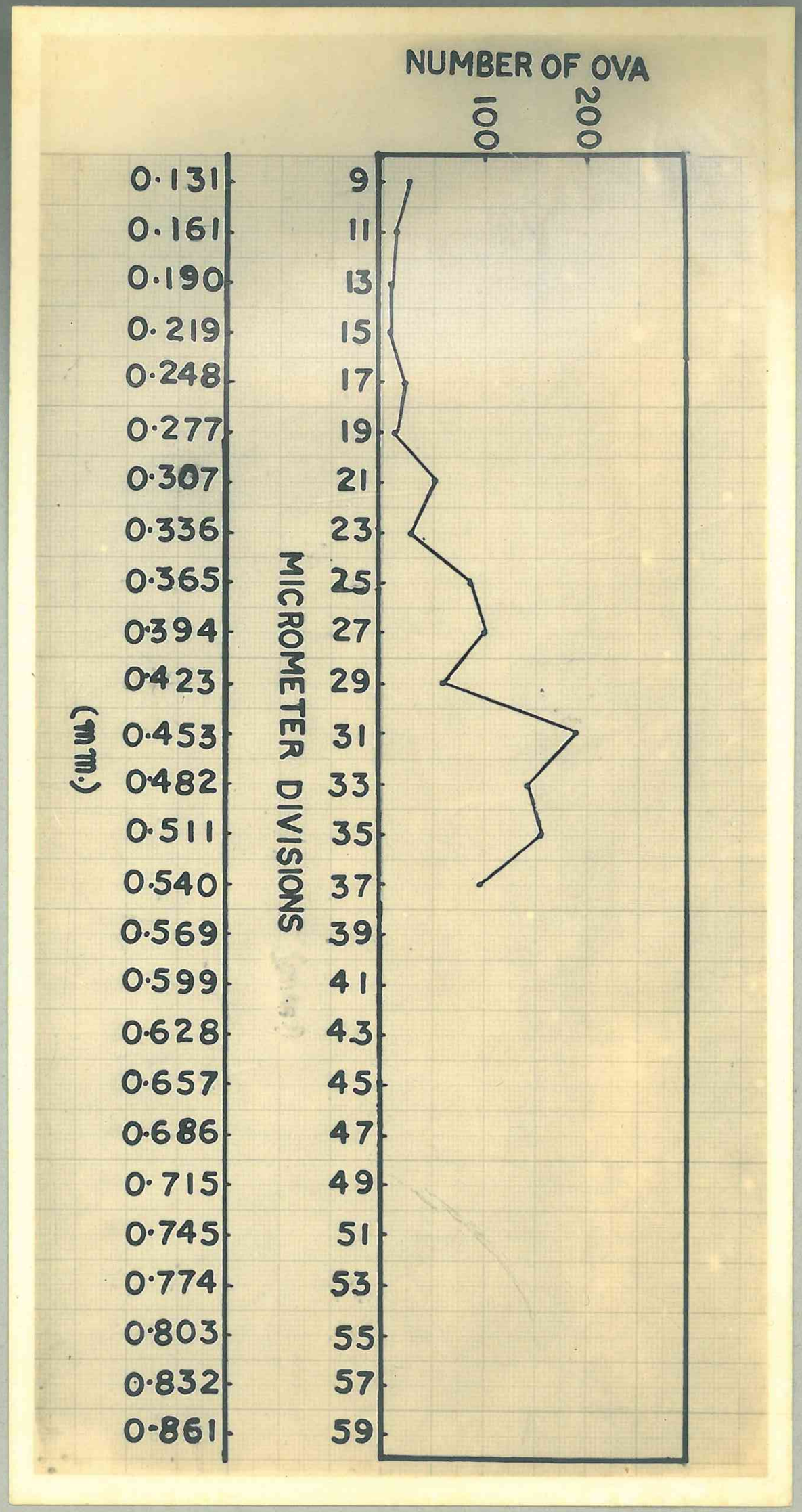

NUMBER OF OVA
100
200
MICROMETER DIVISIONS
(m.m.)
0·131 9
0·161 11
0·190 13
0·219 15
0·248 17
0·277 19
0·307 21
0·336 23
0·365 25
0·394 27
0·423 29
0·453 31
0·482 33
0·511 35
0·540 37
0·569 39
0·599 41
0·628 43
0·657 45
0·686 47
0·715 49
0·745 51
0·774 53
0·803 55
0·832 57
0·861 59

Fig. 2

from other parts of the ovary showed no significant difference in their distribution. The same type of distribution has been found in the right and left lobes of the ovary. Therefore, in all further studies, ova taken from the central portion of the ovary have been utilised.

The ova diameter frequency histograms of samples of 1000 ova each from ovaries in Stages I, II, III, IV, V, VI and VII of maturity are shown in Fig. 3. In Stage I (immature), the ovary predominantly contains small transparent immature ova, measuring a maximum of 0.234 mm. In Stage II (developing immatures and recovering spents), while the majority of ova are small and transparent, a group of ova are withdrawn from the general egg-stock, with a mode at 0.277 mm. and measuring a maximum of 0.350 mm. In Stage III (maturing), a further mode could be noticed at 0.365 mm. and measuring a maximum of 0.438 mm.; the mode at 0.277 mm. is less prominent. The maturing ova of the mode at 0.365 mm. are partly opaque, wherein yolk deposition has commenced around the nucleus and a distinct peripheral zone of cytoplasm is seen under the microscope. In Stage IV (mature), the last mode stands at 0.511 mm., though another mode stands at 0.453 mm. The ova of both modes are fully laden with yolk, opaque and mature, measuring a maximum of 0.555 mm. The mode at 0.394 mm. represent the maturing ova, and the modes at 0.307 mm. and 0.248 mm., the immature ova which are already differentiated from the general egg-stock in the process of maturation. In Stage V (advanced mature), the last mode stands at 0.628 mm. The ova of this mode are in an advanced stage of maturity, opaque, fully laden with yolk, transparent at the periphery and

Fig. 3. Ova diameter frequency histograms of P. waigiensis in Stages I - VII maturity.

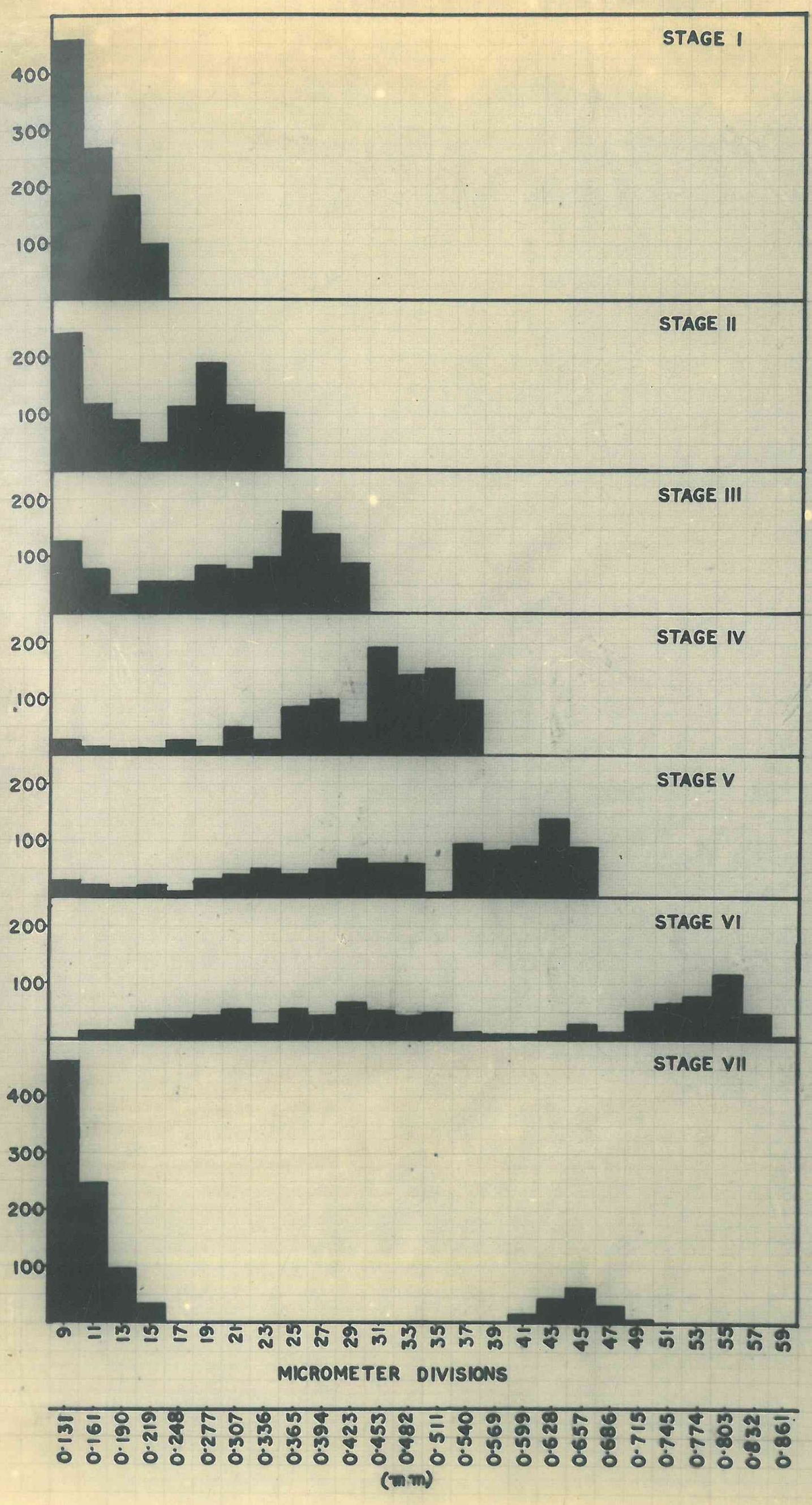

STAGE I
400
300
200
100
STAGE II
200
100
STAGE III
200
100
STAGE IV
200
100
STAGE V
200
100
STAGE VI
200
100
STAGE VII
400
300
200
100
NUMBER OF OVA
9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59
MICROMETER DIVISIONS
0·131 0·161 0·190 0·219 0·248 0·277 0·307 0·336 0·365 0·394 0·423 0·453 0·482 0·511 0·540 0·569 0·599 0·628 0·657 0·686 0·715 0·745 0·774 0·803 0·832 0·861
(mm)

Fig. 3

measure a maximum of 0.672 mm. A group of mature ova stand out with a mode at 0.540 mm. Maturing ova are also demarcated with a mode at 0.423 mm. The modes at 0.336 mm. and 0.219 mm. represent the immature ova. In Stage VI (ripe), the last mode comprising ripe transparent ova stands at 0.803 mm. These ova, each with a single oil globule, measured a maximum of 0.883 mm. in the fresh state. Further, modes occur at 0.657 mm. (advanced mature ova), 0.511 mm. (mature ova), 0.423 mm. and 0.365 mm. (maturing ova), and 0.307 mm. (immature ova). The ovaries in this stage are speckled in appearance. In Stage VII (spent), the ovary contains the general immature egg-stock measuring up to 0.234 mm. and few large residual degenerating ripe ova measuring from 0.584 mm. to 0.730 mm. with a mode at 0.657 mm.

Except in Stages I, II and III, the ova diameter frequency polygons of Stages IV to VI show a number of modes between the mode of smallest ova and the mode of largest ova. The maturing ova are not sharply differentiated from the immature egg-stock. The maturing and mature ova are also not sharply differentiated from each other. These ova pass in succession to advanced stages of maturity, when fresh batches of maturing ova arising from the general egg-stock, take their place. The ripe ova at 0.803 mm. in Stage VI ovary are well defined and are separated from the rest of the stock of ova and these form the first batch of ova to be spawned. By the time this batch of ova is spawned, the ova under the preceding mode at 0.657 mm. get differentiated from the rest of the stock and shift forward replacing the ova spawned, indicating that

the maturation process in the species is gradual and continuous, as has also been found by earlier workers in several species of fish (Clark, 1934; Hickling and Rutenberg, 1936; de Jong, 1940; Palekar and Karandikar, 1952, 1953; Prabhu, 1956; Dharmamba, 1959). The evidence obtained from a fish with ovaries in spent condition (Stage VII) also supports the conclusion that the prominent group of ripe ova noticed in Stage VI ovary is the first batch to be spawned, followed by other spurts of spawning spread over a long period. As there is no sharp separation between the maturing ova and the general stock of eggs, and as the maturing group of ova show a continuous process of maturation, the spawning period in this species appears to be long.

iii. Size at maturity

With a view to determining the size at maturity of P. waigiensis, data on the percentage occurrence of gonads in different stages of maturity in relation to size of fish collected during the course of the study have been analysed. The details are given in Table II. It may be seen from the table that all fish are immature up to 10 cm. total length. A small percentage of fish measuring 10 - 14 cm. are in the maturing stage. Mature fish are first met with in the 14-16 cm. size-group (10.41 per cent) and ripe fish are recorded first in the 16-18 cm. size-group (0.51 per cent). Over 50 per cent of fish in the 22-24 cm. size-group are mature and all fish have been found to mature from 28-30 cm. size-group onward. From the data, it is reasonable to deduce that

the size at first maturity is about 15 cm., majority of fish attain maturity at about 23 cm. and all fish are mature at about 29 cm.

TABLE II

Percentage occurrence of P. waigiensis with gonads in different stages of maturity in relation to size

Size-group (cm.)	Immature I&II	Maturing III	Mature IV&V	Ripe VI	Spent VII
8-10	100.00	--	--	--	--
10-12	92.50	7.50	--	--	--
12-14	90.90	9.10	--	--	--
14-16	50.00	39.59	10.41	--	--
16-18	23.35	54.31	21.83	0.51	--
18-20	11.35	51.89	35.14	1.08	0.54
20-22	3.88	50.39	43.40	2.33	--
22-24	1.72	37.93	55.17	5.18	--
24-26	--	31.82	63.64	4.54	--
26-28	--	20.00	66.67	13.33	--
28-30	--	--	100.00	--	--
30-32	--	--	100.00	--	--
32-34	--	--	50.00	50.00	--
34-36	--	--	100.00	--	--
36-38	--	--	100.00	--	--

iv. Spawning season

a. Maturity stages in different months

Data on the occurrence of fish in various stages of maturity collected during different months of the period June 1955-March 1957 have been utilised. The data are grouped for this study as immature and maturing fish comprising Stages I, II and III and mature and ripe fish comprising Stages IV, V and VI. The percentage of immature and maturing fish and mature and ripe fish during different months are given in Table III. It may be seen from this table that immature and maturing fish were obtained in all months, and mature fish were also obtained in all months, except May and June. Although, mature fish were present in many months, their percentage occurrence was high (over 50 per cent) in November and December. Most of the ripe fish were recorded in December. A similar result has been obtained in two successive years suggesting that the fish spawns over a prolonged period; peak spawning appears to take place during November and December. This conclusion (protracted spawning) is supported by the multiplicity of modes in the ova diameter frequency curves.

b. Average size of the largest intra-ovarian eggs

Data from mature fish (Stage IV and above) on the average size of the largest intra-ovarian eggs collected during the period June 1955-March 1957 have been used. The data are presented in Table IV. The range of the average

TABLE III

Percentage occurrence of P. waigiensis with immature & maturing and mature & ripe gonads in different months (June 1955 - March 1957)

Year and month	No. of fish examined	Immature and Maturing (Stages I, II & III)		Mature and Ripe (Stages IV, V & VI)	
		No.	%	No.	%
1955					
June	15	15	100.00	--	--
July	56	51	91.07	5	8.93
August	73	57	78.09	16	21.91
September	17	12	70.60	5	29.40
October	31	21	67.74	10	32.26
November	23	5	21.73	18	78.27
December	32	10	31.24	21*	65.63
1956					
January	19	11	57.89	8	42.11
February	32	22	68.76	10	31.24
March		No data			
April	27	20	74.06	7	25.94
May	34	34	100.00	--	--
June	37	37	100.00	--	--
July	84	73	86.90	11	13.10
August	79	70	88.61	9	11.39
September	169	130	76.91	39	23.09
October	109	72	66.06	37	33.94
November	141	26	18.44	115	81.56
December	250	70	27.99	180	72.01
1957					
January	20	19	95.01	1	4.99
February	27	19	70.37	8	29.63
March	24	20	83.33	4	16.67
Total	1299	794		504	

*Excluding a female in Stage VII (Spent)

TABLE IV

Average size of the largest intra-ovarian eggs of *P. waigiensis* during different months (June 1955 - March 1957)

Year and month	No. of fish examined	No. of fish in Stages IV, V and VI	Average size of the largest intra-ovarian eggs (mm.)
1955			
June	15	--	--
July	56	5	0.4800
August	73	16	0.5184
September	17	5	0.4800
October	31	10	0.5184
November	23	18	0.5184
December	32	21*	0.5952
1956			
January	19	8	0.4992
February	32	10	0.4992
March		No data	
April	27	7	0.4224
May	34	--	--
June	37	--	--
July	84	11	0.4224
August	79	9	0.4992
September	169	39	0.4608
October	109	37	0.4800
November	141	115	0.4800
December	250	180	0.5952
1957			
January	20	1	0.4608
February	27	8	0.4800
March	24	4	0.4800
Total	1299	504	Grand average 0.4939

*Excluding a female in Stage VII (Spent)

size varies from a minimum of 0.4224 mm. to a maximum of 0.5952 mm. The grand average for the entire period of has been found to be 0.4939 mm. The average size of the largest intra-ovarian eggs was greater than the grand average during August, October, November and December 1955 and January, February, August and December 1956, suggesting that the fish spawns almost throughout the year, intense spawning taking place towards the end of the year.

c. Gonado-somatic index

With a view to studying the seasonal fluctuations in ovary weight in relation to weight of fish as indicative of spawning, the weights of adult females and their ovaries (in different stages of maturity) recorded during the period June 1955-December 1956 have been analysed. For the purpose of this study, the percentage of ovary weight in body weight is defined as the gonado-somatic index. These indices are presented in Table V.

The grand average gonado-somatic index during the entire period has been found to be 2.757. The gonado-somatic indices were greater than the ground average during September, October and November 1955 and January, September, October, November and December 1956, indicating that may take place during these months.

d. Occurrence of ripe fish and young ones

Fourteen females ranging in length from 17.7 cm. to 32.3 cm. in Stage VI (ripe condition) have been recorded

TABLE V

Mean gonado-somatic index of adult females of *P. waigiensis* during different months (June 1955 - December 1956)

Year and month	No. of adult females	Mean gonado-somatic index
1955		
June	--	--
July	5	1.165
August	16	1.663
September	5	2.758
October	10	3.094
November	18	3.427
December	21*	2.502
1956		
January	8	2.976
February	10	2.445
March	No data	
April	7	1.983
May	--	--
June	--	--
July	11	1.687
August	9	2.663
September	39	2.873
October	37	3.480
November	115	4.231
December	180	4.410
Total	491	Grand average 2.757

*Excluding a female in Stage VII (Spent)

during the course of the investigation; of these, one was recorded in April and three in December 1955, one in September and eight in December 1956 and one in January 1958. Two males measuring 21.4 cm. and 21.6 cm. in total length in Stage VI were recorded in December 1956 and January 1958 respectively. The former had asymmetrical testis. Relevant data from the sixteen fish in Stage VI are given in Table VI. Ripe gonads are shown in Photographs 1 to 7.

The large transparent eggs in the thirteen ripe fishes ranged in diameter from 0.672 mm. to 0.883 mm. The egg (Fig.4) is not perfectly spherical and is devoid of chromatophores. The yolk is unsegmented. It has a sigle oil globule. The diameter of the oil globule in different eggs ranged from 0.192 mm. to 0.250 mm. The oil globule is transparent and colourless.

One female measuring 19.6 cm. in total length with ovary in Stage VII (spent) was recorded from Devipatnam in the Palk Bay on 24-12-1955. The ovary (Photograph 2) had a shrunken appearance, resembling ovary in Stage II and contained large residual transparent eggs in its lumen.

Young ones measuring 10 cm. and below in total length appeared in the Mandapam areas (Vedalai and Munakkad) in August 1954, April and November 1955, March, April, May and June 1956 and July, August and September 1957. At Devipatnam, young ones appeared in June 1955 and February, March

TABLE VI

Particulars of 16 specimens of P. waigiensis in Stage VI

Date of collection	Locality	Sex	Total length of fish (cm.)	Weight of fish (gm.)	Length of gonad (cm.)	Width of gonad (cm.)	Weight of gonad (gm.)	Average size of largest eggs (mm.)	Average size of oil globule (mm.)	Fecundity
11- 4-1955	Vedalai	Female	22.5	164	7.0	1.3	5.605	0.768	--	78,940
6-12-1955	"	"	19.3	103	6.2	1.5	9.080	0.672	--	78,940
7-12-1955	"	"	24.0	185	6.8	2.0	14.155	0.730	--	175,900
13-12-1955	"	"	20.5	119	4.3	0.6	2.325	0.883	0.211	16,595
15- 9-1956	"	"	17.7	--	3.2	0.5	--	0.864	0.192	--
11-12-1956	"	"	22.7	144	4.6	1.4	4.252	0.883	0.230	38,750
29-12-1956	Rameswaram	"	27.0	270	8.3	2.7	21.855	0.826	0.250	241,978
"	"	"	26.4	270	7.8	2.8	21.155	0.826	0.250	233,875
"	"	"	25.2	220	8.4	2.8	18.838	0.768	0.230	215,756
"	"	"	23.3	150	6.3	1.6	7.423	0.730	0.230	64,275
"	"	"	22.0	140	6.5	1.7	9.423	0.864	0.230	79,560
"	"	"	22.0	140	7.2	2.3	10.160	0.730	0.230	92,790
"	"	"	19.7	105	4.8	1.2	3.705	0.768	0.230	22,918
16- 1-1958	Near the Research Institute (Gulf of Mannar)	"	32.3	454	6.5	3.5	16.800	0.864	0.211	196,676
20-12-1956	Vedalai	Male	21.4	--	4.0(L.L.) 3.5(R.L.)	1.0(L.L.) 0.4(R.L.)	--	--	--	---
22- 1-1958	"	"	21.6	--	--	--	--	--	--	---

L.L. --- Left lobe
R.L. --- Right lobe

Photograph 1. Left - Stage VI ovary from fish, 22.5 cm. dated 11-4-1955.

Right- Stage VI ovary from fish, 19.3 cm. dated 6-12-1955.

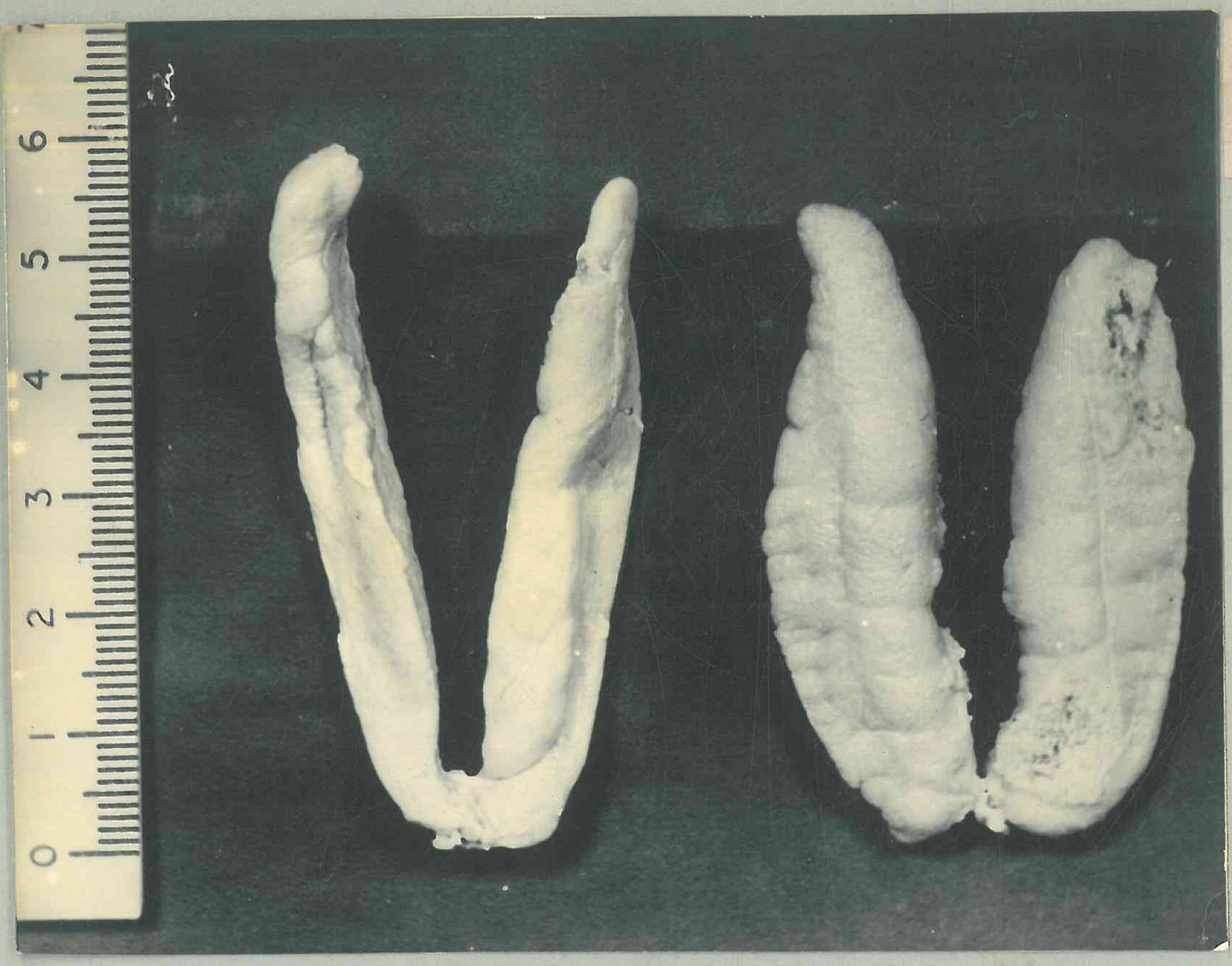
Photograph 2. Left - Stage VII ovary from fish, 19.6 cm. dated 24-12-1955.

Right- Stage VI ovary from fish, 17.7 cm. dated 15-9-1956.

Photograph 3. Stage VI ovaries from seven fishes dated 29-12-1956.

Upper row: Left to right - 27.0 cm., 26.4 cm. and 25.2 cm.

Lower row: Left to right - 23.3 cm., 22.0 cm. 22.0 cm. and 19.7



Photograph 1

Photograph 2

Photograph 3

Photograph 4. Stage VI ovary from fish, 32.3 cm. dated 16-1-1958.

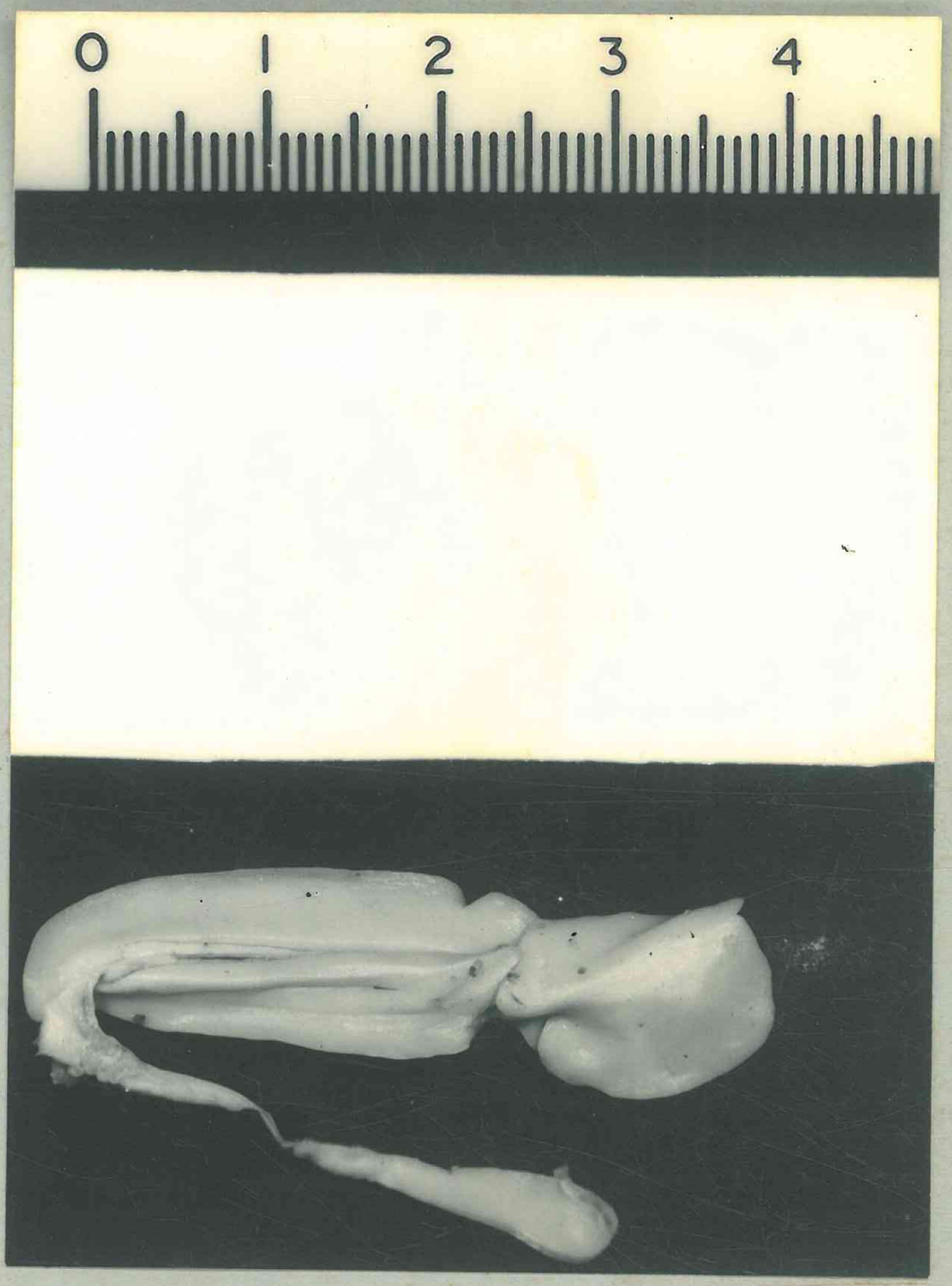
Photograph 5. Portion of Stage VI ovary from fish, 32.3 cm. dated 16-1-1958, showing speckled appearence.

Photograph 4

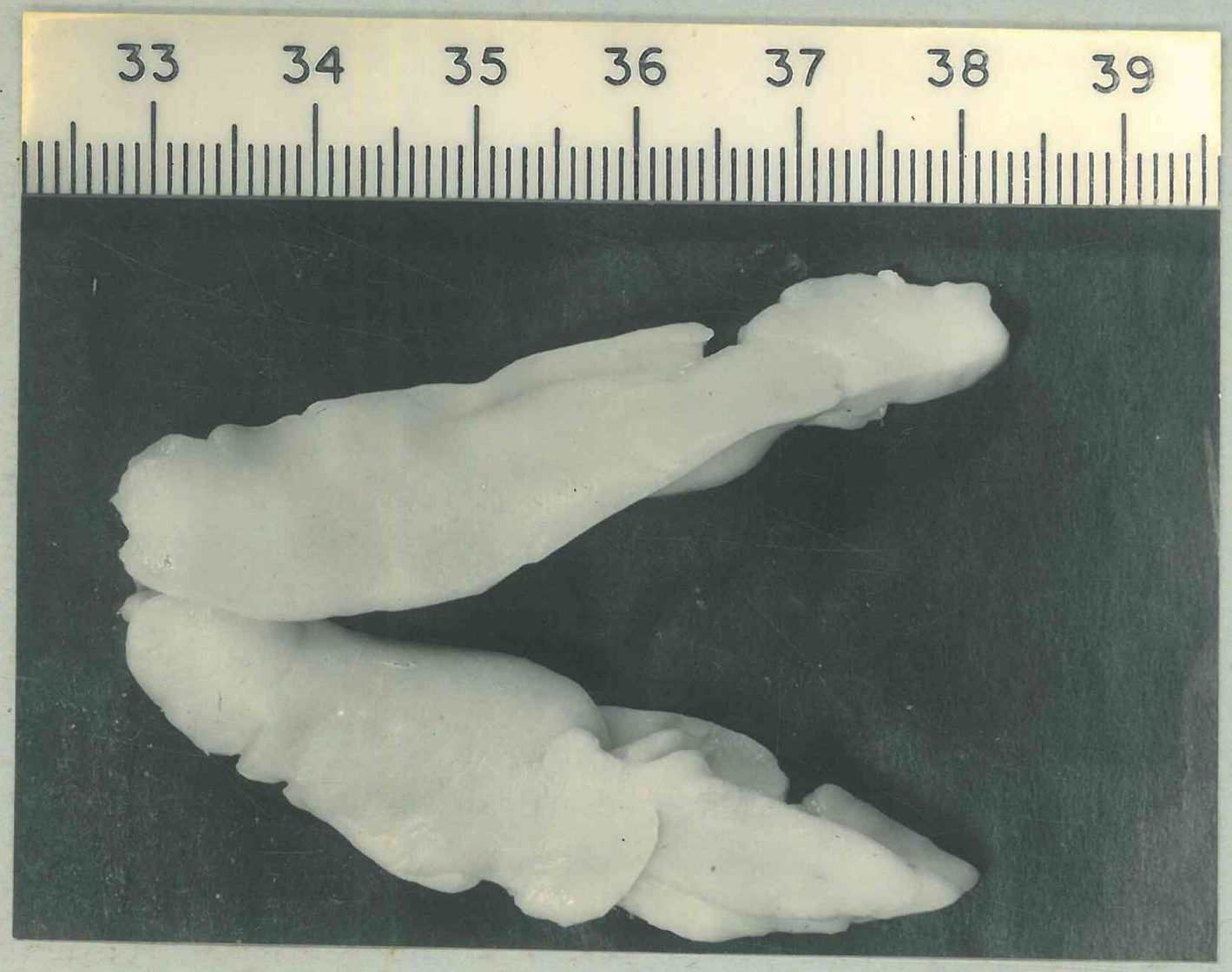
Photograph 5

Photograph 6. Stage VI testis from fish, 21.4 cm.
dated 20-12-1956.

Photograph 7. Stage VI testis from fish, 21.6 cm.
dated 22-1-1958.



Photograph 6



Photograph 7

Fig. 4. Ripe intra-ovarian eggs from fish, 32.3 cm. dated 16-1-1958, in Stage VI maturity.

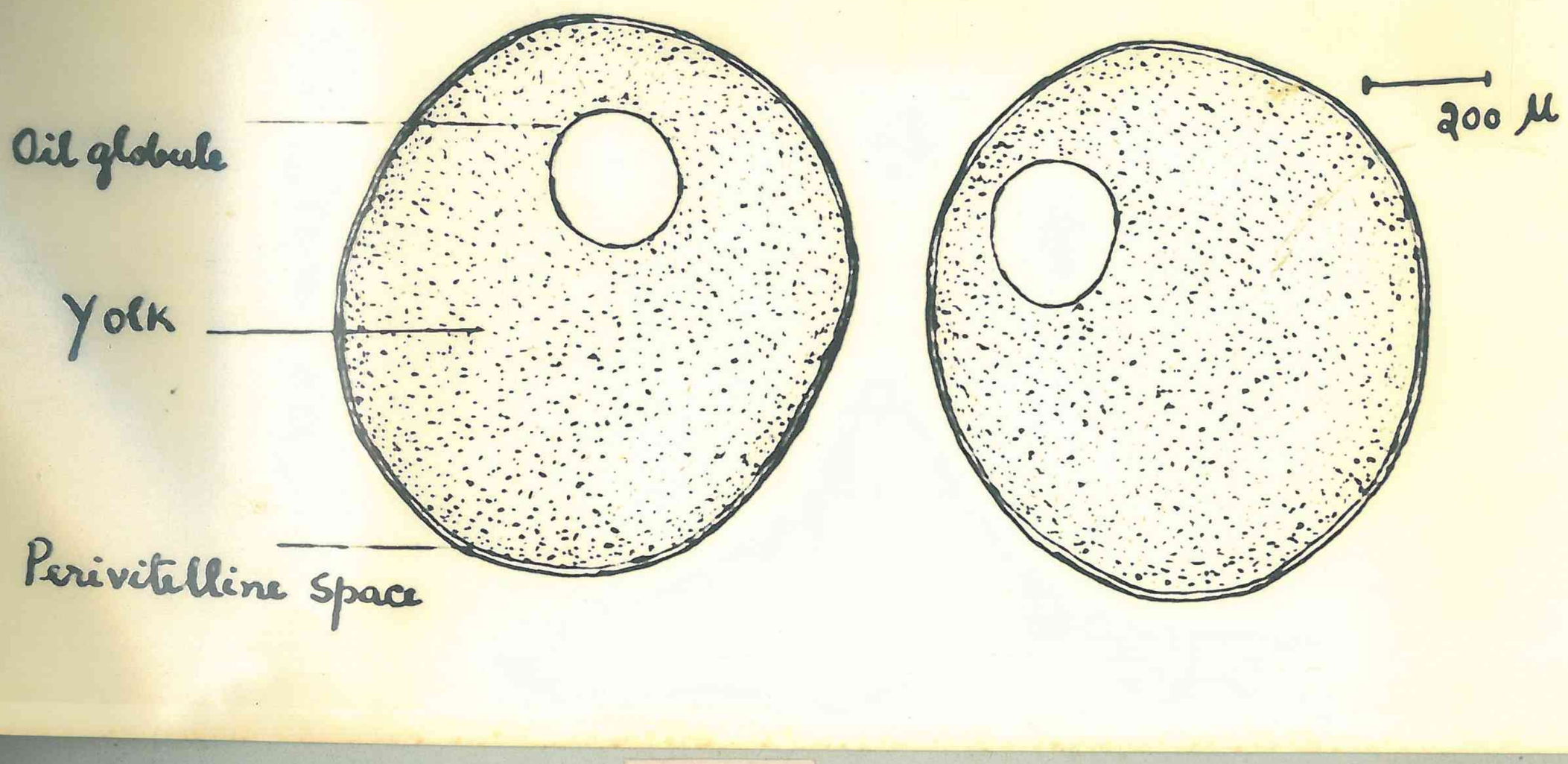


Fig. 4

and April 1956; they did not occur during April 1955. At Tondi, young ones occurred in January, February, March and June 1956. The observations on the occurrence of ripe fish and young ones also support the conclusion that the fish spawns almost throughout the year; intense spawning appears to take place during November and December.

Summarising the observations on the spawning season from the occurrence of maturity stages in different months, monthly fluctuation of average size of the largest intra-ovarian eggs, seasonal variation in gonado-somatic index and relative condition factor and occurrence of ripe fish and young ones, it seems reasonable to conclude that the fish spawns almost throughout the year, except perhaps, during the months of May and June, which may be a resting period. Intense spawning appears to take place during November and December.

v. Frequency of spawning

The multiplicity of modes in the ova diameter frequency curves of mature ovaries of fish suggests that spawning takes place more than once in a season (Clark, 1934; Hickling and Rutenberg, 1936; de Jong, 1940). In P. waigiensis, multiplicity of modes was noticed in the frequency distribution of ova from mature ovaries. As the ripe group of ova is spawned, mature ova of the preceding mode get differentiated and take its place, which in turn are replaced by the maturing group of ova which have undergone half the maturation process. The maturing group of ova take about half the time taken by an

immature group to attain maturity (de Jong, 1940) and, hence , this group will soon be shed in succession to groups of ripe and mature ova. Only one type of spent ovary (fully spent) has been recorded from P. waigiensis. In this ovary, only two types of ova are found - the general immature egg-stock measuring a maximum of 0.234 mm. and a group of residual degenerating ripe ova measuring from 0.584 mm. to 0.730 mm. with a mode at 0.657 mm. This evidence suggests that all the maturing, mature and ripe ova in a Stage VI ovary are shed in succession to one another in spurts of spawning spread over a long time; it is difficult to determine the intervals of time between the spurts of spawning. Owing to the absence of maturing and mature groups of ova from the fully spent ovary, it may be inferred that after the last batch of ripe ova is shed, the ovary takes a long time to return to spawning activity, probably undergoing a resting period.

The frequency histograms of ova from ovaries in Stages IV to VI show a number of modes between the mode of smallest ova and the mode of largest ova. In Stages IV and V, maturing and mature ova are not sharply differentiated from each other, but in Stage VI, the group of ripe ova appears sharply separated from the mature group. The sharp differentiation of the ripe ova from the mature ova tends to indicate that spawning at a time may be of short duration. There is very little progress in the maturing and mature groups of ova till the ripe ova are shed. Once these are shed, their

place is taken up by the mature group whose place in turn is taken up by the maturing group. But, once all the maturing groups of ova are eliminated in successive spurts of spawning activity, only the general egg-stock is left out and a group of ripe degenerating ova, as shown by the fully spent ovary. Since the fish spawns almost throughout the year, it is difficult to indicate the number of times an individual spawns during the protracted spawning activity.

vi. Rate of growth of gonads

With a view to studying the rate of growth of the gonads in relation to the length of fish, the length and width measurements of ovaries and testes of fish of varying lengths, in different stages of maturity, have been recorded and analysed. The following relationships have been found.

Length of fish and length of ovary

The data collected from 123 females ranging in total length between 9.9 cm. and 37.0 cm. have been utilised in this study. The length of fish has been plotted against the length of ovary in a scatter diagram (Fig. 5). The relation appears to be linear and the formula has been found to be:

$$Z = -2.4403 + 0.3268\,X$$

where Z = length of ovary in centimetres and

X = total length of fish in centimetres.

The analysis of variance (Goulden, 1959) given below tests the validity of the linearity of regression.

TABLE VII

Analysis of variance

Source	D.F.	Sum of squares	Mean square	Observed F	Significance
Due to regression	1	214.6913	214.6913	552.3316	**
Deviation from regression	121	47.0338	0.3887		
Total	122	261.7251			

D.F. = Degrees of freedom

** Significant at 1% probability level

The deviation due to regression is highly significant. From Table VII, it may be seen that of the total sum of squares, linear regression removes a little above 80% of the total variation, leaving unexplained the rest of the variation. Since the linear regression removes a little above 80% of the total variation, for all practical purposes, linear relationship could be accepted.

Length of fish and width of ovary

The data collected from 123 females taken for the study of the relationship between length of fish and

length of ovary have been used for this study. The length of fish and width of ovary have been plotted in a scatter diagram (Fig. 6). The relation seems to be linear of the form,

$$U = -1.0571 + 0.0942\,X$$

where U = width of ovary in centimetres and
X = total length of fish in centimetres.

The analysis of variance for testing the validity of the linearity of regression is presented in Table VIII.

TABLE VIII

Analysis of variance

Source	D.F.	Sum of squares	Mean square	Observed F	Significance
Due to regression	1	17.8329	17.8329	179.4054	**
Deviation from regression	121	12.0238	0.0994		
Total	122	29.8567			

D.F. = Degrees of freedom

** Significant at 1% probability level

It is found from the F value that the regression is highly significant. From Table VIII, it may be seen that of the total sum of squares, linear regression

Fig. 5. Relation between length of fish and length of ovary.

Fig. 6. Relation between length of fish and width of ovary.

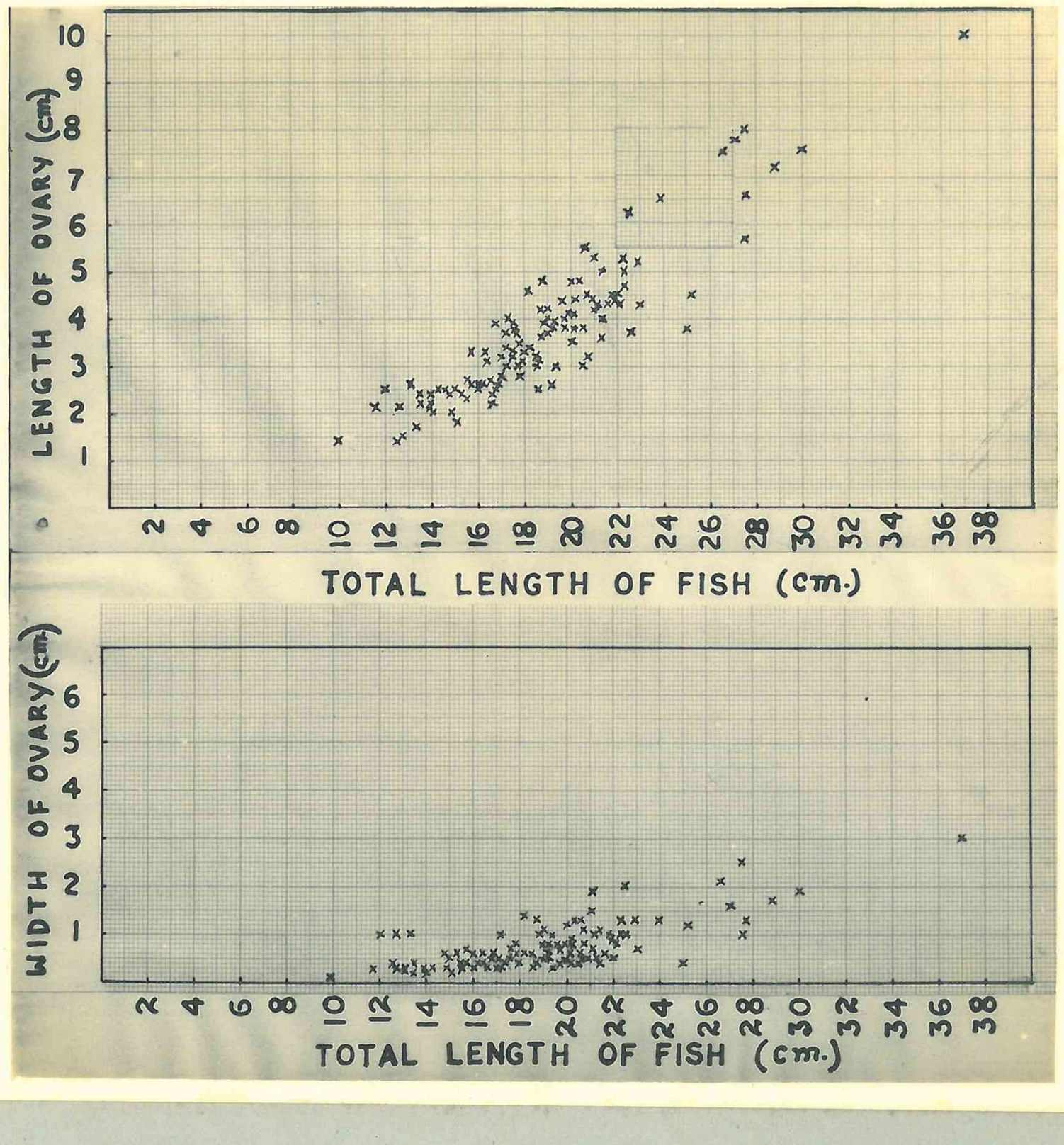

LENGTH OF OVARY (cm)
1 2 3 4 5 6 7 8 9 10
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38
TOTAL LENGTH OF FISH (cm.)
WIDTH OF OVARY (cm.)
1 2 3 4 5 6
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38
TOTAL LENGTH OF FISH (cm.)

Fig. 5

Fig. 6

explains only about 60% of the total variation, showing that probably non-linear relation may explain the total variation in a better way. It is likely that the width of the ovary does not increase proportionately with increase in the length of the fish.

Length of fish and length of testis

The data collected from 111 males ranging in total length between 10.8 cm. and 24.2 cm. have been utilised for this study. The length of fish and length of testis have been plotted in a scatter diagram (Fig.7). The relation is obviously non-linear. But the linear regression,

$$Z = -1.4855 + 0.2706\,X$$

where Z = length of testis in centimetres and

X = total length of fish in centimetres.

removes a major portion of the total variation. This may be seen from the analysis of variance presented in Table IX.

TABLE IX

Analysis of variance

Source	D.F.	Sum of squares	Mean square	Observed F	Significance
Due to regression	1	77.4920	77.4920	318.6349	**
Deviation from regression	109	26.5136	0.2432		
Total	110	104.0056			

D.F. = Degrees of freedom
** Significant at 1% probability level

The linear regression removes nearly 75% of the total variation and hence, for all practical purposes, linear relationship may be accepted.

Length of fish and width of testis

The data collected from 111 males taken for the study of the relationship between length of fish and length of testis have been used in this study. The length of fish and width of testis have been plotted in a scatter diagram (Fig. 8). The relation seems to be linear of the form,

$$U = -0.5100 + 0.0544\,X$$

where U = width of testis in centimetres and
X = total length of fish in centimetres.

The analysis of variance for testing the validity of the linearity of regression is presented in Table X.

TABLE X

Analysis of variance

Source	D.F.	Sum of squares	Mean square	Observed F	Signi-ficance
Due to regression	1	3.1336	3.1336	106.2237	**
Deviation from regression	109	3.2172	0.0295		
Total	110	6.3508			

D.F. = Degrees of freedom
** Significant at 1% probability level

Fig. 7. Relation between length of fish and length of testis.

Fig. 8. Relation between length of fish and width of testis.

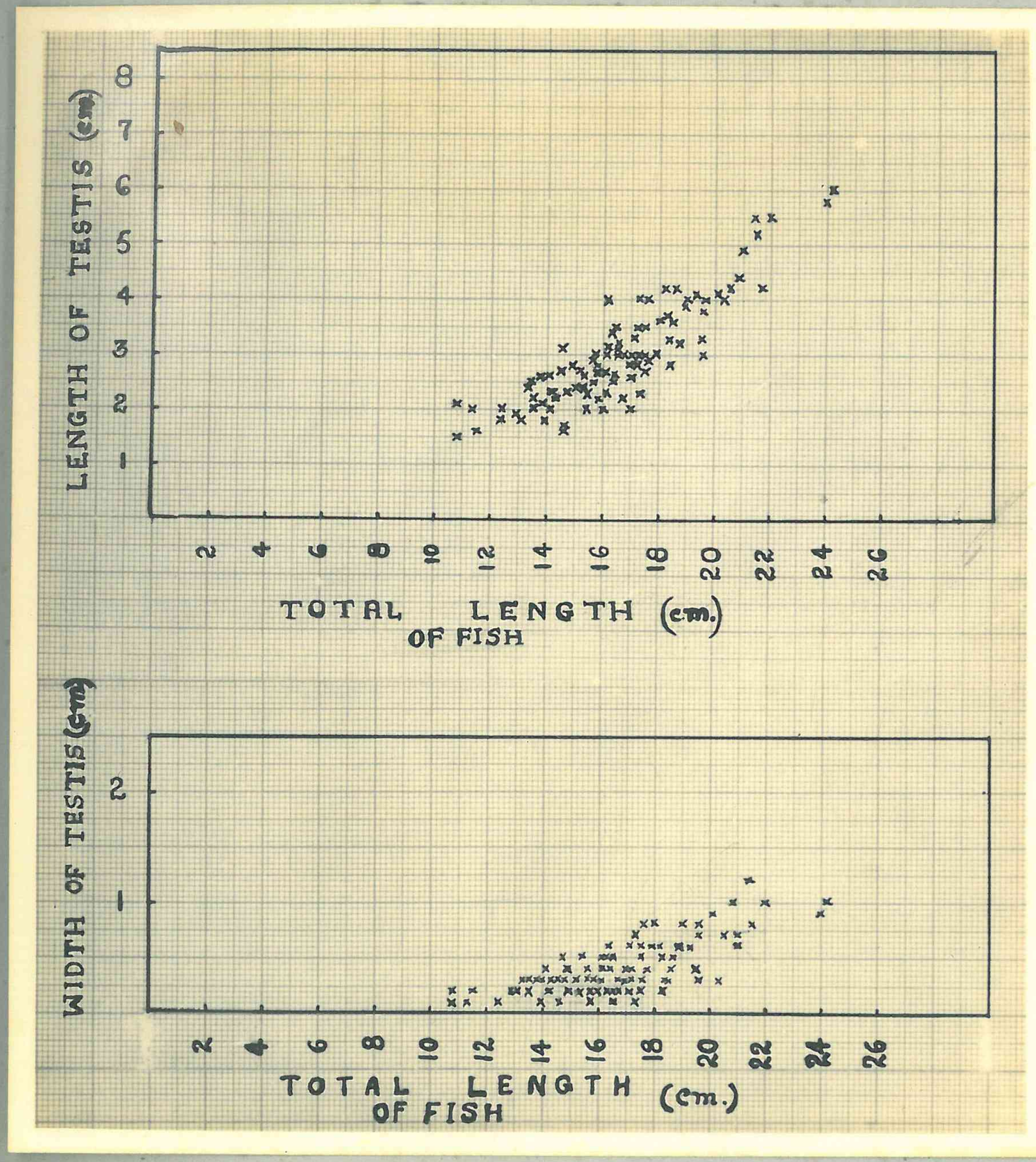

LENGTH OF TESTIS (cm)
1
2
3
4
5
6
7
8
2 4 6 8 10 12 14 16 18 20 22 24 26
TOTAL LENGTH (cm.)
OF FISH
WIDTH OF TESTIS (cm)
1
2
2 4 6 8 10 12 14 16 18 20 22 24 26
TOTAL LENGTH (cm.)
OF FISH

Fig. 7

Fig. 8

It is found from the F value that the regression is highly significant. From Table X, it may be seen that of the total sum of squares, linear regression explains only about 49% of the total variation. This shows that probably non-linear relation may explain the total variation in a better way. It is likely that the width of the testis does not increase proportionately with increase in the length of the fish.

vii. Fecundity

The fecundity of any species of fish is determined from the computed number of ova forming a season's crop. Franz (1910 a and b), and Clark (1934) found that fecundity increased as the square of length. Farran (1938) found that it increased at a rate higher than the fourth power of length. Hickling (1940) found that the fecundity of the herring increased at a rate greater than the third power of its length. Smith (1947) found a straight line relationship between the number of eggs and length of fish in the eastern trout. Simpson (1951) in a study of the fecundity of the plaice, Pleuronectes platessa found that fecundity is related to the cube of length. Lehman (1953) found a correlation between length of fish and fecundity in the shad, Alosa sapidissima by the method of least squares. MacGregor (1957) discussed the relationship between fecundity and length of the Pacific sardine, Sardinops caerulea using different

formulae and concluded that there were no significant differences in the regressions on length, square of length or cube of length. Pillay (1958) found an exponential relationship between fecundity and length of fish and a straight line relationship between fecundity and weight of fish in Hilsa ilisha.

Since P. waigiensis spawns almost throughout the year, multiplicity of modes occurs in the ova diameter frequency curves of mature ovaries. There is no sharp differentiation between the maturing and mature ova and the general egg-stock. But the ripe ova in ripe ovaries are well defined and are separated from the rest of the stock of ova. These form the first batch of ova to be spawned. The number of ova to be spawned at a time by ripe fish is taken as the fecundity. In order to determine the possible number of ova that may be shed immediately by ripe fish, all ova measuring 0.672 mm. and above and which are fully transparent are counted from a sample of ovary of known weight. The total number in the paired ovaries from which the sample had been taken was estimated by multiplying the number counted in the sample by the ratio of the weight of the whole ovary to the weight of the sample. Fecundity estimates were made from ripe ovaries (Stage VI) of 12 specimens collected during the course of the study. Particulars of length of fish, weight of fish, weight of ovary and fecundity are given in Table XI. As may be seen from the table, the possible number of ova that

may be spawned by a fish at a time during the spawning season varies between 16,595 and 241,978.

TABLE XI

Fecundity and other particulars of 12 specimens of P. waigiensis in Stage VI

Total length of fish (cm.)	Weight of fish (gm.)	Weight of ovary (gm.)	Fecundity
19.3	103	9.080	78,940
19.7	105	3.705	22,918
20.5	119	2.325	16,595
22.0	140	9.423	79,560
22.0	140	10.160	92,790
22.7	144	4.252	38,750
23.3	150	7.423	64,275
24.0	185	14.155	175,900
25.2	220	18.838	215,756
26.4	270	21.155	233,875
27.0	270	21,855	241,978
32.3	454	16.800	196,676

a. Relation between fecundity and length of fish

In order to find the relation between fecundity and length of fish, the fecundity estimates obtained for 12 fish have been plotted in a scatter diagram (Fig. 9) and a regression line was fitted to the data by the method of least squares. The equation has been found to be:

$$Y = -305402.04 + 18012.79\ X$$

where Y = fecundity and

X = total length of fish in centimetres.

b. Relation between fecundity and weight of fish

The scatter diagram between fecundity and weight of fish has been plotted in Fig. 10. The relation between the two is curvilinear. Considering the dimensional relationship between body length and body weight which is of the type,

$$W = aL^3$$

and the one between fecundity(F) and body length(L) which has been found to be of the type,

$$F = \alpha + \beta L$$

it was thought that the relation between fecundity and body weight(W) would be of the form,

$$F = A + BW^{\frac{1}{3}}$$

Plotting F against $W^{\frac{1}{3}}$ (Fig. 11), it is found that the relation is linear and may be represented by the empirical relation deduced above on dimensional consideration. Least square estimates of A and B were obtained and the relation has been found to be:

$$F = -318779.55 + 78202.60\ W^{\frac{1}{3}}$$

Fig. 9. Relation between fecundity and length of fish.

Fig.10. Relation between fecundity and weight of fish.

Fig.11. Relation between fecundity and $\sqrt{\text{weight of fish}}$.

Fig.12. Relation between fecundity and weight of ovary.

Fig. 9

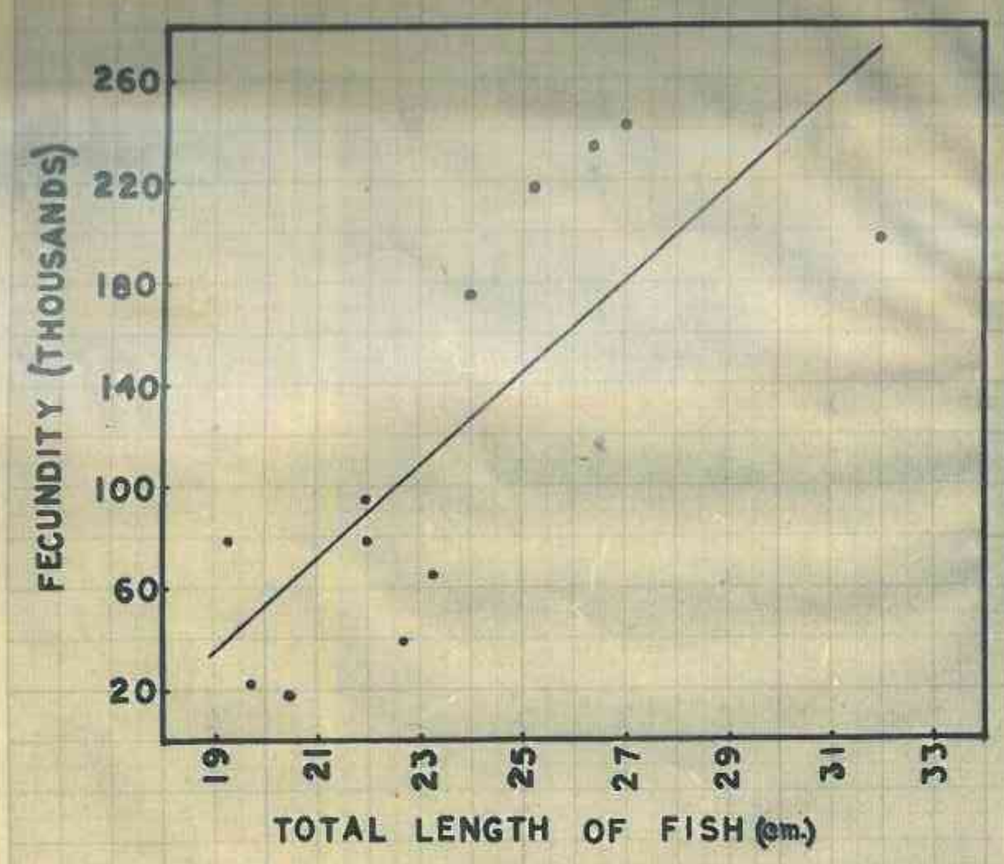


Fig. 10

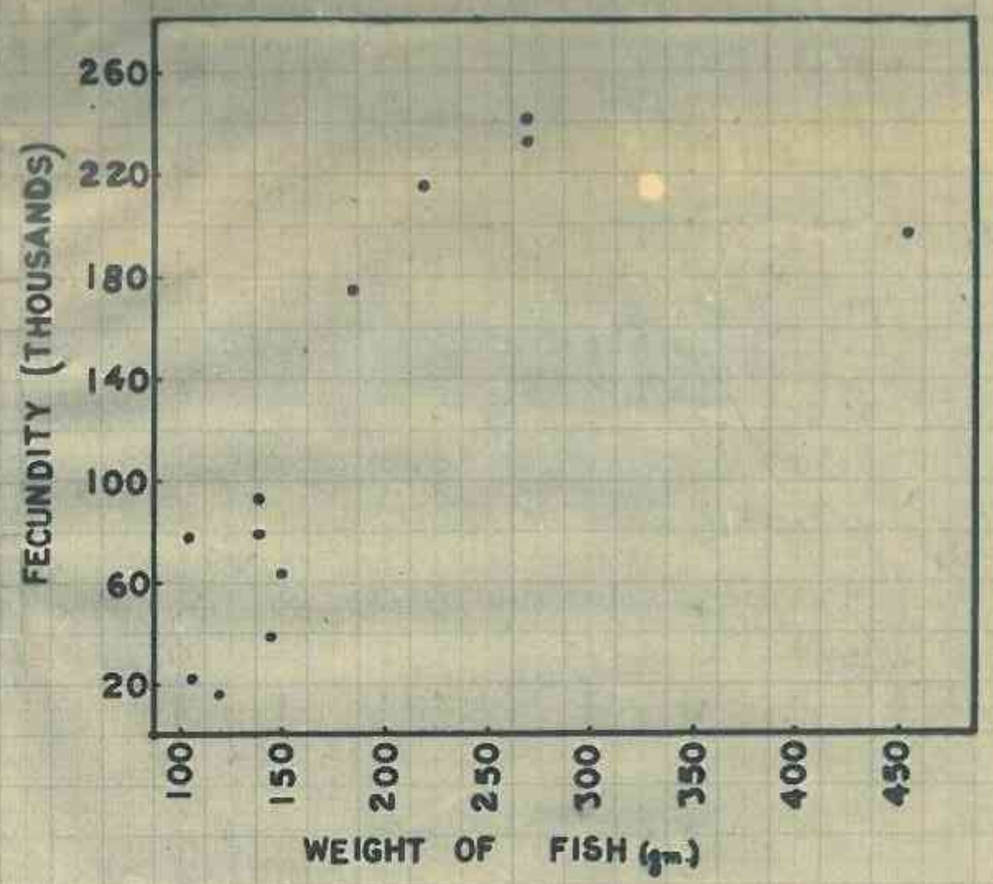


Fig. 11

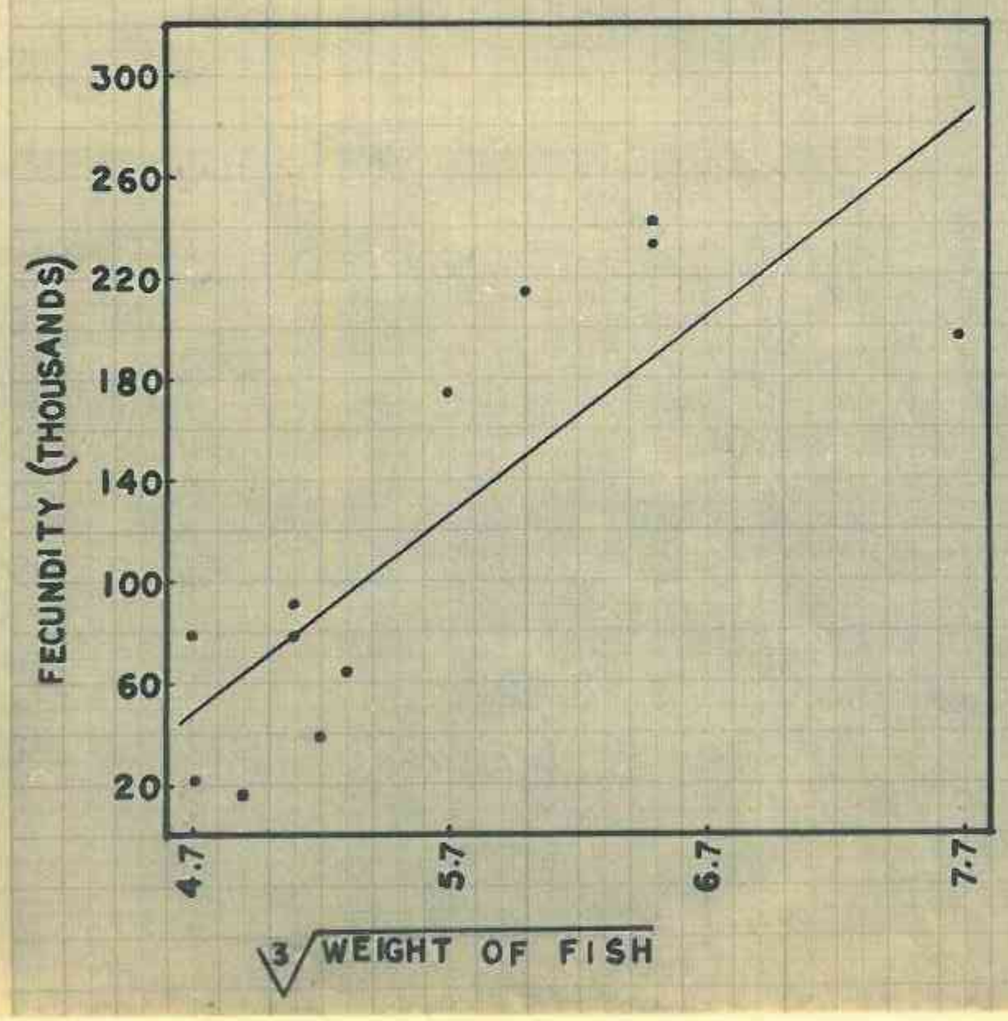
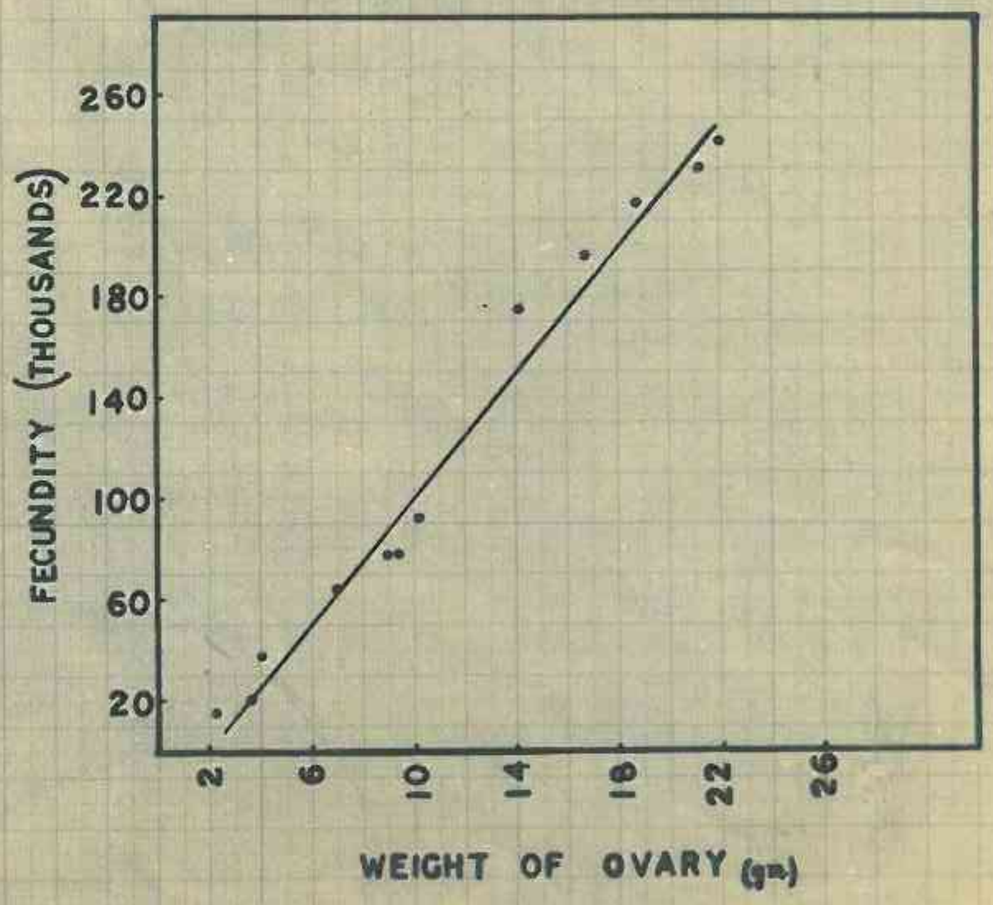


Fig. 12



c. Relation between fecundity and weight of ovary

The relation between fecundity and weight of ovary appeared to be linear as seen in Fig. 12. A regression line was fitted to the data by the method of least squares. The equation has been found to be:

$$Y = -21634.22 + 12339.25\ X$$

where Y = fecundity and

X = weight of ovary in grammes.

viii. Relation between length of fish, weight of fish and weight of ovary

Bal and Joshi (1956) studied the relation between length of fish, weight of fish and weight of ovary in Coilia dussumieri. They found a very high correlation between length of fish and weight of fish, poor correlation between length of fish and weight of ovary and significant correlation between weight of fish and weight of ovary.

For determining the relationship between weight of ovary and weight of fish at various stages of maturity of P. Waigiensis, the weight of the fish Y and the weight of the ovary Z have been taken for 125 fish ranging in total length from 9.9 cm. to 37.0 cm. The object of this study is to find whether length of fish X has an influence on weight of fish Y and weight of ovary Z. Hence, total, partial and multiple correlation coefficients between length of fish (1), weight of fish (2) and weight of ovary (3) were calculated and these are shown in Table XII.

TABLE XII

Total correlation, Partial correlation and Multiple correlation and their Test of Significance

	Total correlation			Partial correlation			Multiple correlation		
	r_{12}	r_{23}	r_{31}	$r_{12.3}$	$r_{13.2}$	$r_{23.1}$	$r_{1.23}$	$r_{2.31}$	$r_{3.12}$
Correlation coefficients	0.92	0.80	0.76	0.80	0.10	0.40	0.92	0.93	0.80
Test of Significance	t 26.03	t 14.79	t 12.97	t 14.73	t 1.40	t 4.82	F 340.1	F 408.6	F 110.8
D.F.	123	123	123	123	123	123	(123,2)	(123,2)	(123,2)
5% Value	1.96	1.96	1.96	1.96	1.96	1.96	19.49	19.49	19.49

D.F. = Degrees of freedom

Total correlation

It may be seen from Table XII that a very high correlation exists between length of fish and weight of fish, as may be expected. A good correlation exists between weight of fish and weight of ovary and between length of fish and weight of ovary. These total correlation coefficients, however, do not clearly bring out the exact relationship existing between the characters. To test the influence of one character on others, partial correlation coefficients were calculated.

Partial correlation

Partial correlation coefficient between length of fish and weight of fish, when weight of ovary is constant, has been found to be $r_{12.3}$= 0.80. This is almost of the same order of magnitude as the total correlation coefficient r_{12} (correlation between length of fish and weight of fish), showing that weight of ovary has practically no influence on the relation between length of fish and weight of fish. This is clearly brought out in the partial correlation coefficient $r_{13.2}$= 0.10, which shows that for constant weight of fish, there is no significant correlation between length of fish and weight of ovary. For constant length of fish, the partial correlation coefficient between weight of fish and weight of ovary, though significant, is small.

Multiple correlation

The effect on length of fish due to the variations in weight of fish and weight of ovary is shown by $r_{1.23}$. This is seen to be highly significant. Since $r_{12} = r_{1.23} = 0.92$, it is evident that the effect on length of fish must be mainly due to the effect of weight of fish. Similarly, when the length of fish and weight of ovary are allowed to vary, the value of the weight of fish is much affected. This must also be primarily due to the influence of variation in length of fish. Similarly, weight of ovary is also found to be significantly affected by joint variations in length of fish and weight of fish, as is seen from the value of $r_{3.12}$. As was shown, the significant influence must be mainly due to the influence of weight of fish on weight of ovary.

ix. Sex ratio

Sex ratio studies are an essential aspect of fishery biological studies providing information whether one sex dominates over the other in the population as a whole, whether males and females move in separate shoals, whether one sex outnumbers the other during the spawning seasons as a consequence of spawning migration and whether differential fishing exists with respect to the males and the females.

The distribution of sexes at Tondi (Palk Bay) during the period September 1955-June 1956 is shown in Table XIII.

TABLE XIII

Sex ratio of P. waigiensis at Tondi
(September 1955 - June 1956)

Year and month	Males	Females	Total	p = ratio of males to total
1955				
September	8	3	11	0.7273
October	21	16	37	0.5676
November	30	16	46	0.6522
December		No data		
1956				
January	17	33	50	0.3400
February	20	30	50	0.4000
March	24	15	39	0.6154
April		No data		
May		No data		
June	20	30	50	0.4000
Total	140	143	283	$\bar{p}$=0.4947 $\bar{q}$=0.5053

$\chi^2(1 : 1)$ = 18.38 for 6 Degrees of freedom

$\chi^2(\bar{p} : \bar{q})$ = 18.38 for 6 Degrees of freedom

First, the hypothesis of equality of distribution of sexes in different months was tested by calculating the chi-square value as per the formula given below:

$$\chi^2(1:1) = \frac{\Sigma px - \bar{p}\Sigma x}{0.50 \times 0.50}$$

where p = proportion of males

$\bar{p}$ = mean proportion of males and

x = number of males.

The chi-square value was found to be 18.38. A reference to chi-square table with 6 degrees of freedom shows that the hypothesis of equality of sex distribution during different months cannot be accepted. Obviously, males were in preponderance between September and November 1955 and in March 1956. Tests were also made to find out if the same sex ratio was being maintained between different months. This was done by calculating chi-square as per formula given below:

$$\chi^2(\bar{p} : \bar{q}) = \frac{\Sigma px - \bar{p}\Sigma x}{\bar{p}\,\bar{q}}$$

where $\bar{q} = 1 - \bar{p}$ and

other symbols are same as before.

The chi-square value was found to be 18.38 with 6 degrees of freedom showing that the same sex ratio was not being maintained in different months.

The distribution of sexes at Devipatnam (Palk Bay) during the period September 1955-May 1956 is shown in

Table XIV. The proportion of males vary from 0.16 to 0.42 over the months for which the data are available. First, chi-square calculated for testing the equality of sex ratio in different months gave the value 14.26 with 7 degrees of freedom. This has been found to be highly significant indicating that the equality of sex distribution over the months cannot be accepted. Next, chi-square calculated to see if the same sex ratio was being maintained over the months gave the value 17.21 with 7 degrees of freedom. This again has been found to be highly significant showing that the same sex ratio was also not being maintained over the months.

TABLE XIV

Sex ratio of P. waigiensis at Devipatnam
(September 1955 - May 1956)

Year and month	Males	Females	Total	p = ratio of males to total
1955				
September	19	26	45	0.4222
October	16	39	55	0.2909
November	20	31	51	0.3922
December	8	42	50	0.1600
1956				
January	6	29	35	0.1714
February	17	29	46	0.3696
March	12	33	45	0.2667
April	1	3	4	0.2500
May	--	7	7	0.0000
Total	99	239	338	$\bar{p}$=0.2929 $\bar{q}$=0.7071

χ^2 (1 : 1) = 14.26 for 7 Degrees of freedom

χ^2 ($\bar{p}$: $\bar{q}$) = 17.21 for 7 Degrees of freedom

The distribution of sexes at Munakkad (Palk Bay) during the period June 1955-September 1957 is shown in Table XV. During the ten months, males were always less than the females. To test if this same ratio holds good for all months, the chi-square value was found to be 11.09 for 9 degrees of freedom showing significant differences in sex ratio between months.

The distribution of sexes at Vedalai (Gulf of Mannar) during the period August 1955-September 1957 is shown in Table XVI. For testing the equality of sex ratio, chi-square was found to be 83.04 for 16 degrees of freedom. This has been found to be highly significant. For testing as to whether the same sex ratio was maintained in different months, chi-square was found to be 87.41 for 16 degrees of freedom. This has been found to be very significant.

At Tondi, males were found in a proportion higher than the mean from September to November 1955 and March 1956, at Devipatnam, in September and November 1955 and February 1956, at Munakkad in July 1955, June and August 1956 and July and September 1957 and at Vedalai, in November 1955, November 1956 and January and May 1957. Since the fishing operations are conducted in the inshore waters, the above observations may mean the migration of the females to offshore waters during these months.

During the period of study (September 1955-June 1956) at Tondi, the mean ratio of males to females

TABLE XV

Sex ratio of P. waigiensis at Munakkad
(June 1955 - September 1957)

Year and month	Males	Females	Total	p= ratio of males to total
1955				
June	5	15	20	0.2500
July	39	80	119	0.3277
August	3	9	12	0.2500
September to December	No data			
1956				
January to May	No data			
June	13	37	50	0.2600
July	18	84	102	0.1765
August	30	79	109	0.2752
September and October	No data			
November	11	42	53	0.2075
December	No data			
1957				
January to June	No data			
July	13	31	44	0.2955
August	1	13	14	0.0714
September	9	18	27	0.3333
	142	408	550	$\bar{p}$=0.2582 $\bar{q}$=0.7418

$\chi^2(1 : 1) = 8.50$ for 9 Degrees of freedom
$\chi^2(\bar{p} : \bar{q}) = 11.09$ for 9 Degrees of freedom

TABLE XVI

Sex ratio of P. waigiensis at Vedalai
(August 1955 - September 1957)

Year and month	Males	Females	Total	p= ratio of males to total
1955				
August	32	75	107	0.2991
September	13	22	35	0.3714
October	19	36	55	0.3454
November	19	29	48	0.3958
December	15	52	67	0.2239
1956				
January	--	19	19	0.0000
February	7	32	39	0.1795
March		No data		
April	18	46	64	0.2812
May	29	53	82	0.3536
June to August		No data		
September	95	169	264	0.3598
October	63	109	172	0.3663
November	257	297	554	0.4639
December	287	487	774	0.3708
1957				
January	128	112	240	0.5333
February	12	33	45	0.2667
March	14	35	49	0.2857
April		No data		
May	28	17	45	0.6222
June to August		No data		
September	21	43	64	0.3281
	1057	1666	2723	$\bar{p}$=0.3882 $\bar{q}$=0.6118

$\chi^2(1 : 1) = 83.04$ for 16 Degrees of freedom
$\chi^2(\bar{p} : \bar{q}) = 87.41$ for 16 Degrees of freedom

(0.49 : 0.51) approximates the theoretically expected ratio (0.50 : 0.50); whereas at Devipatnam, the mean sex ratio obtaining during almost the same period (September 1955-May 1956) was different (males to females 0.29 : 0.71). At Munakkad and Vedalai, the mean ratios of males to females (0.26 : 0.74 and 0.39 : 0.61 respectively) are comparable with that at Devipatnam. At both the places, females predominated over males during the period June 1955-September 1957, except in January and May 1957 at Vedalai.

CHAPTER 3

AGE AND GROWTH

The age and growth of fishes are generally determined by two methods - i. Length-frequency analysis and ii. by a study of the seasonal marks on the skeletal structures like the scales, otoliths, etc.

i. Length-frequency analysis

The main principles governing this method may briefly be stated as follows:

1. A population of a species of fish having a single restricted spawning season has the lengths of individuals of each age-group approximately normally distributed.

2. Growth is such that the modes of the length distributions of successive age-groups in a sample taken from the population are separated along the length axis and may be easily distinguished.

3. A polymodal curve results from the length-frequency distribution of a sample containing many age-groups, the separate modes of which represent the approximate mean sizes of the constituent age-groups.

Although this method is strictly applicable to fish with a single restricted spawning season, it has been applied here to derive supporting evidence regarding the age and growth of P. waigiensis. The modes have been traced keeping in view the prolonged spawning nature of the species.

The total length of fresh fish has been used in this study. The data presented here relate to four centres Vedalai, Munakkad, Devipatnam and Tondi.

Vedalai and Munakkad

Fishing at Vedalai lasts for eight months in a year, viz., January to April and September to December and at Munakkad for the rest of the year. Two types of gear, viz., traps and shore seines account for the landings at Vedalai and Munakkad. The data collected during the period July 1954-October 1957 were, therefore, analysed gear-wise and habitat-wise (Table XVII) to find whether changes in the gear used or habitat fished account for the apparent stability of some modes and shift of other modes in some months. Gear-wise and combined length-frequency curves for Vedalai and Munakkad are given in Figs. 13, 14 and 15. Fish in different length ranges were caught by traps and shore seines. However, as could be seen from Table XVII and Figs. 13 and 14, data collected from trap and shore seine landings gave almost similar modal values through different months during the period of study.

TABLE XVII

Length-frequency distributions (gear-wise) of P. waigiensis at Vedalai (Gulf of Mannar) and Munakkad (Palk Bay)
(July 1954 - October 1957)

Size-group (cm.)	1954																							
	July						August						September						October					
	Munakkad						Munakkad						Vedalai						Vedalai					
	Traps		Shore seines		Combined		Traps		Shore seines		Combined		Traps		Shore seines		Combined		Traps		Shore seines		Combined	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
6- 7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7- 8	--	--	--	--	--	--	--	--	11	2.8	11	1.3	--	--	--	--	--	--	--	--	--	--	--	--
8- 9	--	--	--	--	--	--	--	--	13	3.4	13	1.6	--	--	--	--	--	--	--	--	--	--	--	--
9-10	--	--	--	--	--	--	--	--	40	10.4	40	4.8	--	--	--	--	--	--	--	--	--	--	--	--
10-11	--	--	7	63.6	7	1.2	--	--	72	18.6	72	8.7	--	--	3	2.1	3	0.6	1	0.1	--	--	1	0.1
11-12	--	--	1	9.1	1	0.2	3	0.7	89	23.1	92	11.1	2	0.5	8	5.7	10	1.9	1	0.1	3	7.1	4	0.5
12-13	2	0.3	1	9.1	3	0.5	9	2.0	61	15.8	70	8.5	14	3.6	24	16.9	38	7.2	10	1.3	1	2.4	11	1.4
13-14	10	1.7	--	--	10	1.6	19	4.3	32	8.3	51	6.2	62	16.1	20	14.2	82	15.5	55	7.1	8	19.0	63	7.7
14-15	20	3.4	1	9.1	21	3.5	24	5.4	10	2.6	34	4.1	58	15.0	8	5.7	66	12.5	114	14.8	13	31.0	127	15.6
15-16	43	7.2	--	--	43	7.1	36	8.1	8	2.1	44	5.3	57	14.8	4	2.8	61	11.5	147	19.0	10	23.8	157	19.3
16-17	91	15.4	--	--	91	15.1	49	11.1	4	1.0	53	6.4	45	11.6	5	3.5	50	9.5	113	14.6	3	7.1	116	14.2
17-18	122	20.6	--	--	122	20.2	69	15.6	7	1.8	76	9.2	28	7.3	8	5.7	36	6.8	80	10.4	1	2.4	81	9.9
18-19	108	18.3	--	--	108	17.9	73	16.5	12	3.1	85	10.3	28	7.3	3	2.1	31	5.9	73	9.4	1	2.4	74	9.1
19-20	90	15.3	--	--	90	14.9	65	14.7	10	2.6	75	9.1	26	6.7	4	2.8	30	5.7	55	7.1	2	4.8	57	7.0
20-21	53	9.0	--	--	53	8.8	40	9.0	5	1.3	45	5.4	20	5.2	4	2.8	24	4.6	54	7.0	--	--	54	6.6
21-22	27	4.5	1	9.1	28	4.6	26	5.9	10	2.6	36	4.4	14	3.6	6	4.2	20	3.8	34	4.4	--	--	34	4.2
22-23	14	2.3	--	--	14	2.3	10	2.3	--	--	10	1.2	17	4.3	3	2.1	20	3.8	17	2.2	--	--	17	2.1
23-24	6	1.0	--	--	6	1.0	11	2.5	--	--	11	1.3	4	1.0	5	3.5	9	1.7	13	1.7	--	--	13	1.6
24-25	4	0.6	--	--	4	0.7	3	0.7	2	0.5	5	0.6	5	1.3	4	2.8	9	1.7	3	0.4	--	--	3	0.4
25-26	1	0.2	--	--	1	0.2	2	0.5	--	--	2	0.2	1	0.3	6	4.2	7	1.3	1	0.1	--	--	1	0.1
26-27	1	0.2	--	--	1	0.2	2	0.5	--	--	2	0.2	3	0.8	4	2.8	7	1.3	--	--	--	--	--	--
27-28	--	--	--	--	--	--	1	0.2	--	--	1	0.1	1	0.3	5	3.5	6	1.1	2	0.3	--	--	2	0.2
28-29	--	--	--	--	--	--	--	--	--	--	--	--	1	0.3	7	4.9	8	1.5	--	--	--	--	--	--
29-30	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7	4.9	7	1.3	--	--	--	--	--	--
30-31	--	--	--	--	--	--	--	--	--	--	--	--	--	--	4	2.8	4	0.8	--	--	--	--	--	--
31-32	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
32-33	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
33-34	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
34-35	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
35-36	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
36-37	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total	592		11		603		442		386		828		386		142		528		773		42		815	

Continued

TABLE XVII (Continued)

Length-frequency distributions (gear-wise) of P. waigiensis at Vedalai (Gulf of Mannar) and Munakkad (Palk Bay)
(July 1954 - October 1957)

Size-group (cm.)	1954												1955									
	November						December						January, February and March	April		May					June	
	Vedalai						Vedalai							Vedalai		Munakkad					Munakkad	
	Traps		Shore seines		Combined		Traps		Shore seines		Combined			Shore seines		Traps		Shore seines		Combined	Traps	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%		No.	%	No.	%	No.	%	No.	%	No.	%
6- 7	--	--	--	--	--	--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--
7- 8	--	--	--	--	--	--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--
8- 9	--	--	--	--	--	--	--	--	--	--	--	--		1	1.5	--	--	--	--	--	--	--	--
9-10	--	--	--	--	--	--	--	--	--	--	--	--		4	5.9	--	--	--	--	--	--	--	--
10-11	--	--	--	--	--	--	--	--	--	--	--	--		2	3.0	--	--	--	--	--	--	2	0.2
11-12	--	--	--	--	--	--	--	--	--	--	--	--		4	5.9	--	--	--	--	--	--	4	0.4
12-13	2	0.5	--	--	2	0.5	--	--	--	--	--	--		6	9.0	--	--	--	--	--	--	17	1.8
13-14	1	0.3	--	--	1	0.2	3	0.9	--	--	3	0.8		7	10.5	2	2.4	--	--	2	2.0	31	3.3
14-15	22	5.5	3	7.7	25	5.8	9	2.7	--	--	9	2.5		3	4.5	3	3.6	--	--	3	3.0	52	5.5
15-16	64	16.2	12	30.8	76	17.5	34	10.3	3	10.7	37	10.3		3	4.5	10	11.9	2	11.8	12	11.9	101	10.7
16-17	84	21.2	7	17.9	91	21.0	81	24.5	8	28.6	89	24.8		5	7.5	5	6.0	3	17.6	8	7.9	148	15.7
17-18	61	15.4	5	12.9	66	15.2	74	22.4	5	17.8	79	22.0		7	10.4	19	22.6	2	11.8	21	20.8	156	16.5
18-19	47	11.8	7	17.9	54	12.4	49	14.8	3	10.7	52	14.5		1	1.5	12	14.3	4	23.5	16	15.8	109	11.5
19-20	30	7.6	2	5.1	32	7.4	35	10.6	4	14.3	39	10.9		2	3.0	9	10.7	6	35.3	15	14.9	108	11.4
20-21	27	6.8	3	7.7	30	6.9	13	3.9	1	3.6	14	3.9		1	1.5	6	7.1	--	--	6	5.9	83	8.8
21-22	15	3.8	--	--	15	3.5	10	3.0	2	7.1	12	3.3		5	7.5	8	9.5	--	--	8	7.9	56	5.9
22-23	11	2.8	--	--	11	2.5	12	3.6	1	3.6	13	3.7		9	13.4	7	8.3	--	--	7	6.9	48	5.1
23-24	13	3.3	--	--	13	3.0	4	1.2	--	--	4	1.1		3	4.5	1	1.2	--	--	1	1.0	18	1.9
24-25	5	1.3	--	--	5	1.2	--	--	1	3.6	1	0.3		4	5.9	1	1.2	--	--	1	1.0	8	0.9
25-26	4	1.0	--	--	4	0.9	3	0.9	--	--	3	0.8		--	--	1	1.2	--	--	1	1.0	1	0.1
26-27	1	0.3	--	--	1	0.2	4	1.2	--	--	4	1.1		--	--	--	--	--	--	--	--	1	0.1
27-28	3	0.8	--	--	3	0.7	--	--	--	--	--	--		--	--	--	--	--	--	--	--	1	0.1
28-29	3	0.8	--	--	3	0.7	--	--	--	--	--	--		--	--	--	--	--	--	--	--	1	0.1
29-30	1	0.3	--	--	1	0.2	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--
30-31	--	--	--	--	--	--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--
31-32	--	--	--	--	--	--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--
32-33	--	--	--	--	--	--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--
33-34	1	0.3	--	--	1	0.2	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--
34-35	--	--	--	--	--	--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--
35-36	--	--	--	--	--	--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--
36-37	--	--	--	--	--	--	--	--	--	--	--	--		--	--	--	--	--	--	--	--	--	--
Total	395		39		434		331		28		359			67		84		17		101		945	

Size-group (cm.)

Continued

TABLE XVII (Continued)

Length-frequency distributions (gear-wise) of P. waigiensis at Vedalai (Gulf of Mannar) and Munakkad (Palk Bay) (July 1954 - October 1957)

Size-group (cm.)	1955																					
	July		August						September		October						November					
	Munakkad		Vedalai						Vedalai		Vedalai						Vedalai		Munakkad		Vedalai&Munakkad	
	Traps		Traps		Shore seines		Combined		Traps		Traps		Shore seines		Combined		Traps		Shore seines		Combined	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
6- 7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7- 8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	2.7	2	0.9
8- 9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	16	21.1	16	7.0
9-10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	11	14.5	11	4.8
10-11	--	--	--	--	--	--	--	--	1	0.8	--	--	--	--	--	--	--	--	10	13.2	10	4.4
11-12	1	0.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	3	3.9	3	1.3
12-13	3	0.7	9	3.6	--	--	9	3.4	1	0.8	1	0.5	1	2.0	2	0.8	--	--	3	3.9	3	1.3
13-14	14	3.3	9	3.6	--	--	9	3.4	4	3.4	3	1.4	7	14.0	10	3.9	--	--	--	--	--	--
14-15	17	4.0	26	10.4	--	--	26	9.8	12	10.2	31	14.8	4	8.0	35	13.5	1	0.7	--	--	1	0.4
15-16	33	7.7	39	15.7	--	--	39	14.7	27	23.0	39	18.7	17	34.0	56	21.6	2	1.3	--	--	2	0.9
16-17	54	12.5	35	14.1	--	--	35	13.3	28	23.7	44	21.0	5	10.0	49	18.9	21	13.7	--	--	21	9.2
17-18	82	19.1	27	10.8	--	--	27	10.2	18	15.3	34	16.3	7	14.0	41	15.8	38	24.8	6	7.9	44	19.2
18-19	66	15.4	22	8.8	--	--	22	8.3	6	5.1	12	5.7	2	4.0	14	5.4	35	22.9	7	9.2	42	18.3
19-20	49	11.4	26	10.4	--	--	26	9.8	9	7.6	18	8.6	4	8.0	22	8.5	23	15.0	5	6.6	28	12.2
20-21	39	9.1	21	8.4	--	--	21	7.9	6	5.1	8	3.8	2	4.0	10	3.9	12	7.9	4	5.3	16	7.0
21-22	31	7.2	5	2.0	--	--	5	1.9	4	3.4	5	2.4	1	2.0	6	2.3	7	4.6	--	--	7	3.1
22-23	15	3.5	11	4.5	--	--	11	4.2	--	--	2	1.0	--	--	2	0.8	6	3.9	2	2.6	8	3.5
23-24	9	2.1	11	4.5	1	7.0	12	4.5	1	0.8	6	2.0	--	--	6	2.3	4	2.6	3	3.9	7	3.1
24-25	3	0.7	4	1.6	3	19.5	7	2.7	--	--	1	0.5	--	--	1	0.4	--	--	1	1.3	1	0.4
25-26	5	1.2	3	1.2	3	19.5	6	2.3	--	--	3	1.4	--	--	3	1.1	1	0.7	--	--	1	0.4
26-27	2	0.5	--	--	1	7.0	1	0.4	1	0.8	--	--	--	--	--	--	3	1.9	1	1.3	4	1.8
27-28	3	0.7	--	--	2	13.0	2	0.8	--	--	2	1.0	--	--	2	0.8	--	--	1	1.3	--	--
28-29	1	0.2	1	0.4	1	7.0	2	0.8	--	--	--	--	--	--	--	--	--	--	--	--	1	0.4
29-30	2	0.5	--	--	2	13.0	2	0.8	--	--	--	--	--	--	--	--	--	--	--	--	--	--
30-31	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	1.3	1	0.4
31-32	-	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
32-33	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
33-34	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
34-35	--	--	--	--	1	7.0	1	0.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--
35-36	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
36-37	--	--	--	--	1	7.0	1	0.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total	429		249		15		264		118		209		50		259		153		176		229	

Continued

TABLE XVII (Continued)

Length-frequency distributions (gear-wise) of P. waigiensis at Vedalai (Gulf of Mannar) and Munakkad (Palk Bay) (July 1954 - October 1957)

Size-group (cm.)	1955						1956													
	December						January		February		March		April		May					
	Vedalai						Vedalai		Vedalai		Vedalai		Vedalai		Munakkad		Vedalai		Munakkad and Vedalai	
	Traps		Shore seines		Combined		Traps		Traps		Traps		Shore seines		Traps		Shore seines		Combined	
	No.	%	No.	%.	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
6- 7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7- 8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
8- 9	--	--	--	--	--	--	--	--	--	--	--	--	1	0.4	--	--	--	--	--	--
9-10	--	--	--	--	--	--	--	--	--	--	-1	0.7	1	0.4	--	--	7	1.9	7	1.3
10-11	--	--	--	--	--	--	--	--	--	--	2	1.3	3	1.1	1	0.6	9	2.4	10	1.9
11-12	8	0.9	--	--	8	0.7	--	--	1	0.4	5	3.2	12	4.2	3	1.8	18	4.9	21	4.0
12-13	40	4.5	2	0.9	42	3.8	1	0.6	7	2.6	8	5.2	21	7.4	1	0.6	48	13.2	49	9.2
13-14	82	9.2	9	4.2	91	8.3	6	3.8	17	6.3	4	2.6	27	9.5	3	1.8	62	17.1	65	12.2
14-15	93	10.5	13	6.1	106	9.6	9	5.7	31	11.4	14	9.0	39	13.6	11	6.5	54	14.9	65	12.2
15-16	116	13.1	36	16.8	152	13.8	13	8.2	27	10.0	43	27.7	36	12.6	19	11.2	61	16.8	80	15.0
16-17	89	10.0	11	5.1	100	9.1	11	7.0	33	12.2	18	11.6	25	8.8	27	15.9	39	10.7	66	12.4
17-18	109	12.3	29	13.5	138	12.5	14	8.9	31	11.4	15	9.7	43	15.0	24	14.2	29	8.0	53	10.0
18-19	126	14.2	26	12.2	152	13.8	24	15.2	34	12.5	12	7.7	36	12.5	25	14.7	22	6.1	47	8.8
19-20	93	10.0	30	14.0	123	11.2	25	15.8	29	10.7	9	5.8	11	3.9	26	15.4	7	1.9	33	6.2
20-21	75	8.5	27	12.6	102	9.2	23	14.6	28	10.3	8	5.1	13	4.6	5	3.0	1	0.3	6	1.1
21-22	32	3.6	13	6.1	45	4.1	11	7.0	22	8.1	5	3.2	10	3.5	10	6.0	2	0.6	12	2.3
22-23	9	1.0	6	2.8	15	1.4	7	4.4	7	2.6	4	2.6	4	1.4	6	3.5	1	0.3	7	1.3
23-24	7	0.8	6	2.8	13	1.2	5	3.2	2	0.7	--	--	2	0.7	3	1.8	2	0.6	5	0.9
24-25	5	0.6	3	1.4	8	0.7	4	2.5	--	--	2	1.3	--	--	3	1.8	1	0.3	4	0.8
25-26	1	0.1	1	0.5	2	0.2	1	0.6	1	0.4	--	--	--	--	2	1.2	--	--	2	0.4
26-27	2	0.2	--	--	2	0.2	1	0.6	--	--	2	1.3	--	--	--	--	--	--	--	--
27-28	--	--	1	0.5	1	0.1	2	1.3	1	0.4	--	--	1	0.4	--	--	--	--	--	--
28-29	--	--	--	--	--	--	1	0.6	--	--	2	1.3	--	--	--	--	--	--	--	--
29-30	--	--	1	0.5	1	0.1	--	--	--	--	1	0.7	--	--	--	--	--	--	--	--
30-31	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
31-32	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
32-33	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
33-34	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
34-35	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
35-36	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
36-37	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total	887		214		1101		158		271		155		285		169		363		532	

Continued

TABLE XVII (Continued)

Length-frequency distributions (gear-wise) of P. waigiensis at Vedalai (Gulf of Mannar) and Munakkad (Palk Bay)
(July 1954 - October 1957)

Size-group (cm.)	1956 June		July		August	September		October		November				December				1957 January			
	Munakkad		Munakkad			Vedalai		Vedalai		Vedalai	Munakkad	Vedalai and Munakkad		Vedalai	Munakkad	Vedalai and Munakkad		Vedalai			
	Traps		Traps			Traps		Traps		Traps	Shore seines	Combined		Traps	Shore seines	Combined		Traps		Shore seines		Combined	
	No.	%	No.	%		No.	%	No.	%	No.	No.	No.	%	No.	No.	No.	%	No.	%	No.	%	No.	%
6- 7	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7- 8	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
8- 9	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
9-10	1	0.1	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10-11	1	0.1	--	--		--	--	--	--	--	--	--	--	--	1	2.0	1	0.2	--	--	--	--	--
11-12	1	0.1	1	0.3		--	--	--	--	--	2	1.6	2	0.3	--	--	--	--	--	--	--	--	--
12-13	9	1.1	5	1.4		1	1.7	1	0.4	--	10	7.9	10	1.6	--	--	2	3.9	2	0.5	--	--	--
13-14	65	7.5	24	7.0		5	8.4	11	4.0	3	12	9.5	15	2.3	5	1.4	2	3.9	7	1.7	--	--	--
14-15	141	16.3	45	13.0		6	10.2	32	11.7	9	14	11.1	23	3.6	23	6.2	8	15.6	31	7.4	4	3.9	--
15-16	189	21.9	87	25.1		7	11.9	65	23.8	55	24	19.1	79	12.2	86	23.2	3	5.9	89	21.0	25	24.3	2
16-17	161	18.6	83	24.0		10	16.9	69	25.3	124	23.9	13	10.3	137	21.2	57	15.4	1	2.0	58	13.8	36	34.9	6
17-18	80	9.3	51	14.7		11	18.6	43	15.7	142	27.3	12	9.5	154	23.9	45	12.1	3	5.9	48	11.4	20	19.4	6
18-19	60	6.9	26	7.5		8	13.6	24	8.8	93	17.9	13	10.3	106	16.4	50	13.5	12	23.5	62	14.7	11	10.7	1
19-20	52	6.0	11	3.2		6	10.2	17	6.2	62	11.9	9	7.1	71	11.0	44	11.9	4	7.8	48	11.4	2	1.9	--
20-21	43	5.0	7	2.0		2	3.4	2	0.7	19	3.7	6	4.8	25	3.9	29	7.8	1	2.0	30	7.1	3	2.9	--
21-22	23	2.7	2	0.6		--	--	6	2.2	6	1.2	3	2.4	9	1.4	13	3.5	7	13.7	20	4.7	1	1.0	--
22-23	23	2.7	2	0.6		1	1.7	1	0.4	1	0.2	2	1.6	3	0.5	5	1.3	1	2.0	6	1.4	--	--	--
23-24	11	1.3	2	0.6		2	3.4	1	0.4	3	0.6	3	2.4	6	0.9	5	1.3	2	3.9	6	1.4	--	--	--
24-25	1	0.1	--	--		--	--	--	--	--	--	2	1.6	2	0.3	1	0.3	--	--	2	0.5	--	--	--
25-26	3	0.3	--	--		--	--	--	--	1	0.2	1	0.8	2	0.3	2	0.5	1	2.0	3	0.7	--	--	--
26-27	--	--	--	--		--	--	1	0.4	1	0.2	--	--	1	0.2	2	0.5	3	5.9	5	1.2	1	1.0	--
27-28	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
28-29	--	--	--	--		--	--	--	--	--	--	--	--	--	--	2	0.5	--	--	2	0.5	--	--	--
29-30	--	--	--	--		--	--	--	--	--	--	--	--	--	--	1	0.3	--	--	1	0.2	--	--	--
30-31	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
31-32	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
32-33	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
33-34	--	--	--	--		--	--	--	--	--	--	--	--	--	--	1	0.3	--	--	1	0.2	--	--	--
35-36	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
36-37	--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total	864		346			59		273		519	126			645	871			51		422		103		15	118

Continued

TABLE XVII (Continued)

Length-frequency distributions (gear-wise) of P. waigiensis at Vedalai (Gulf of Mannar) and Munakkad (Palk Bay)
(July 1954 - October 1957)

Size-group (cm.)	1957																					
	February		March						April	May		June	July		August		September					October
	Vedalai		Vedalai							Vedalai			Munakkad		Munakkad		Vedalai		Munakkad		Vedalai and Munakkad		Vedalai	
	Traps		Traps		Shore seines		Combined			Shore seines			Shore seines		Shore seines		Traps		Shore seines		Combined		Traps	
	No.	%	No.	%	No.	%	No.	%		No.	%		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
6- 7	--	--	--	--	--	--	--	--		--	--		1	1.0	1	0.6	--	--	--	--	--	--	--	--
7- 8	--	--	--	--	--	--	--	--		--	--		12	12.5	1	0.6	--	--	1	4.0	1	1.6	--	--
8- 9	--	--	--	--	--	--	--	--		--	--		10	10.5	14	9.0	--	--	--	--	--	--	--	--
9-10	--	--	--	--	--	--	--	--		--	--		5	5.2	19	12.2	--	--	---	--	--	--	--	--
10-11	--	--	--	--	1	7.1	1	0.9		--	--		15	15.7	29	18.6	--	--	--	--	--	--	--	--
11-12	1	0.8	--	--	1	7.1	1	0.9		--	--		8	8.4	22	14.1	--	--	3	12.0	3	4.8	--	--
12-13	3	2.3	1	1.0	1	7.1	2	1.8		2	2.7		13	13.6	18	11.6	--	--	--	--	--	--	--	--
13-14	3	2.3	3	3.0	1	7.1	4	3.5		7	9.6		10	10.5	21	13.5	1	2.7	6	24.0	7	11.4	1	4.3
14-15	5	3.9	5	4.9	--	--	5	4.3		10	13.7		5	5.2	6	3.8	6	16.2	4	16.0	10	16.1	2	8.7
15-16	20	15.3	10	9.9	2	14.4	12	10.4	∞	14	19.2	∞	5	5.2	6	3.8	4	10.9	3	12.0	7	11.4	1	4.3
16-17	16	12.3	15	14.9	3	21.5	18	15.7		13	17.8		5	5.2	2	1.3	8	21.6	2	8.0	10	16.1	2	8.7
17-18	10	7.7	14	13.9	1	7.1	15	13.0	↩	12	16.4	↩	--	--	3	1.9	7	18.9	3	12.0	10	16.1	4	17.4
18-19	5	3.9	5	5.9	--	--	6	5.2	∞	6	8.2	∞	1	1.0	7	4.5	7	18.9	1	4.0	8	12.9	3	13.1
19-20	22	16.9	16	15.8	2	14.4	18	15.7		2	2.7		--	--	--	--	2	5.4	--	--	2	3.2	3	13.1
20-21	25	19.2	9	8.9	--	--	9	7.8	♂	4	5.5	♂	2	2.0	--	--	1	2.7	--	--	1	1.6	2	8.7
21-22	12	9.2	15	14.9	--	--	15	13.0		1	1.4		--	--	4	2.6	--	--	--	--	--	--	3	13.1
22-23	5	3.9	5	4.9	1	7.1	6	5.2	♀	1	1.4	♀	1	1.0	2	1.3	--	--	1	4.0	1	1.6	1	4.3
23-24	1	0.8	2	2.0	1	7.1	3	2.6	⚥	1	1.4	⚥	1	1.0	--	--	--	--	--	--	--	--	1	4.3
24-25	2	1.5	--	--	--	--	--	--		--	--		--	--	--	--	1	2.7	--	--	1	1.6	--	--
25-26	--	--	--	--	--	--	--	--		--	--		--	--	--	--	--	--	--	--	--	--	--	--
26-27	--	--	--	--	--	--	--	--		--	--		1	1.0	1	0.6	--	--	1	4.0	1	1.6	--	--
27-28	--	--	--	--	--	--	--	--		--	--		--	--	--	--	--	--	--	--	--	--	--	--
28-29	--	--	--	--	--	--	--	--		--	--		--	--	--	--	--	--	--	--	--	--	--	--
29-30	--	--	--	--	--	--	--	--		--	--		1	1.0	--	--	--	--	--	--	--	--	--	--
30-31	--	--	--	--	--	--	--	--		--	--		--	--	--	--	--	--	--	--	--	--	--	--
31-32	--	--	--	--	--	--	--	--		--	--		--	--	--	--	--	--	--	--	--	--	--	--
32-33	--	--	--	--	--	--	--	--		--	--		--	--	--	--	--	--	--	--	--	--	--	--
33-34	--	--	--	--	--	--	--	--		--	--		--	--	--	--	--	--	--	--	--	--	--	--
34-35	--	--	--	--	--	--	--	--		--	--		--	--	--	--	--	--	--	--	--	--	--	--
35-36	--	--	--	--	--	--	--	--		--	--		--	--	--	--	--	--	--	--	--	--	--	--
36-37	--	--	--	--	--	--	--	--		--	--		--	--	--	--	--	--	--	--	--	--	--	--
Total	130		101		14		115			73			96		156		37		25		62		23	

Fig. 13. Length-frequency distributions of P. waigiensis (from trap landings) at Vedalai (V) and Munakkad (M).
(July 1954 - October 1957)

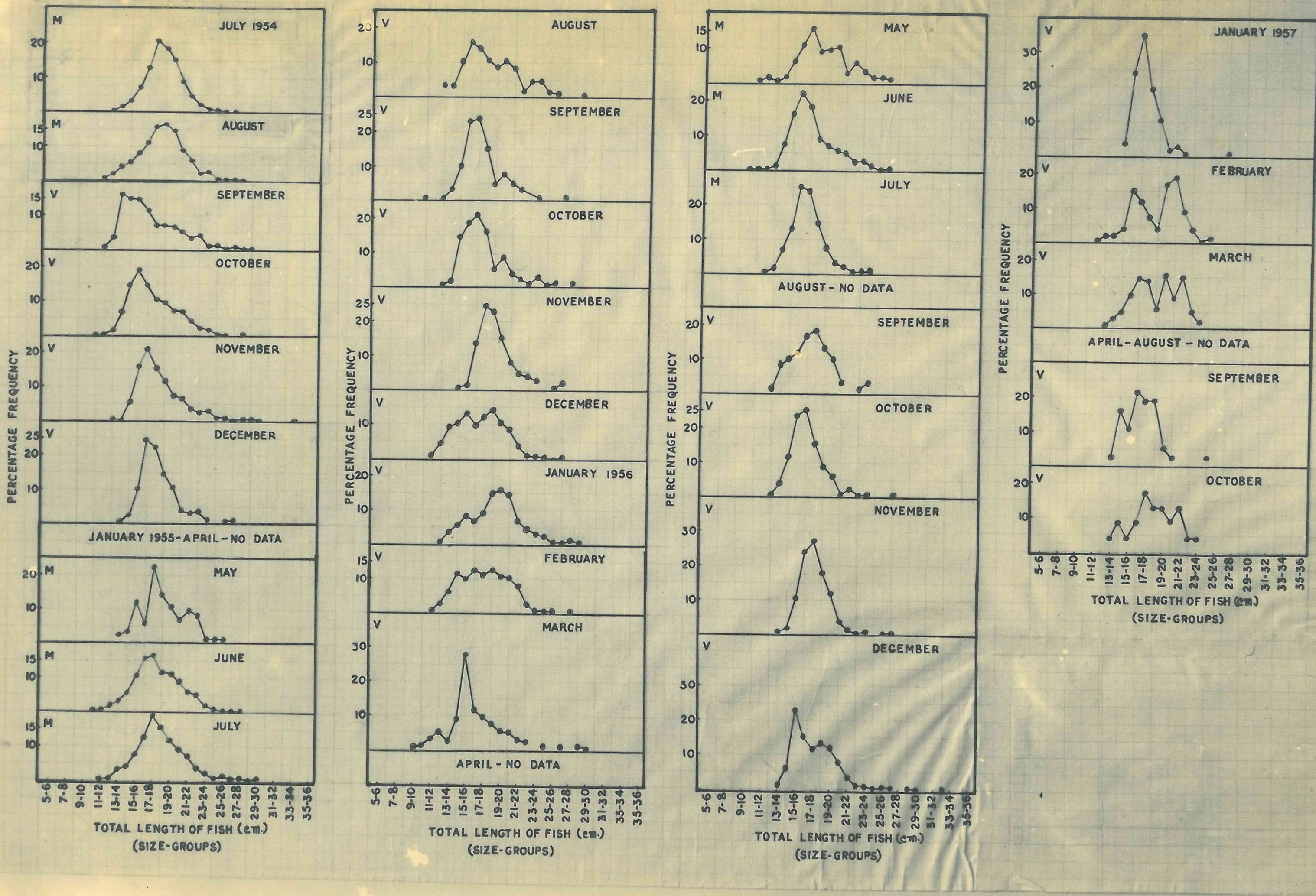

JULY 1954
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY 1955-APRIL-NO DATA
MAY
JUNE
JULY
PERCENTAGE FREQUENCY
TOTAL LENGTH OF FISH (cm.)
(SIZE-GROUPS)
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY 1956
FEBRUARY
MARCH
APRIL - NO DATA
MAY
JUNE
JULY
AUGUST - NO DATA
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY 1957
FEBRUARY
MARCH
APRIL - AUGUST - NO DATA
SEPTEMBER
OCTOBER

Fig. 13

Fig. 14. Length-frequency distributions of P. waigiensis (from shore seine landings) at Vedalai (V) and Munakkad (M).
(July 1954 - September 1957)

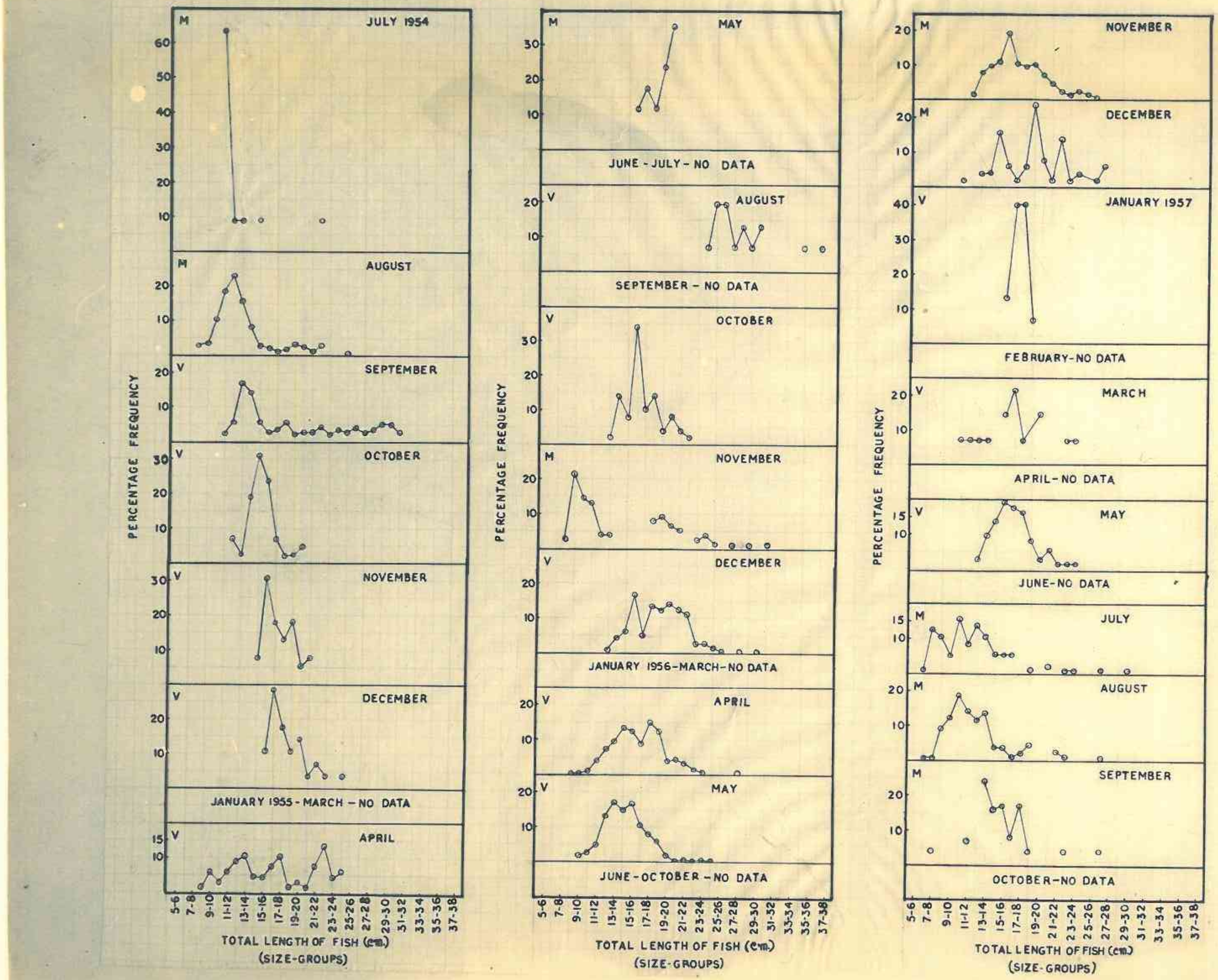

JULY 1954
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY 1955 - MARCH - NO DATA
APRIL
MAY
JUNE - JULY - NO DATA
AUGUST
SEPTEMBER - NO DATA
OCTOBER
NOVEMBER
DECEMBER
JANUARY 1956 - MARCH - NO DATA
APRIL
MAY
JUNE - OCTOBER - NO DATA
NOVEMBER
DECEMBER
JANUARY 1957
FEBRUARY - NO DATA
MARCH
APRIL - NO DATA
MAY
JUNE - NO DATA
JULY
AUGUST
SEPTEMBER
OCTOBER - NO DATA
PERCENTAGE FREQUENCY
TOTAL LENGTH OF FISH (cm.)
(SIZE-GROUPS)

Fig. 14

Fig. 15. Length-frequency distributions of P. waigiensis (combined data) at Vedalai (V) and Munakkad (M).
(July 1954 - October 1957)

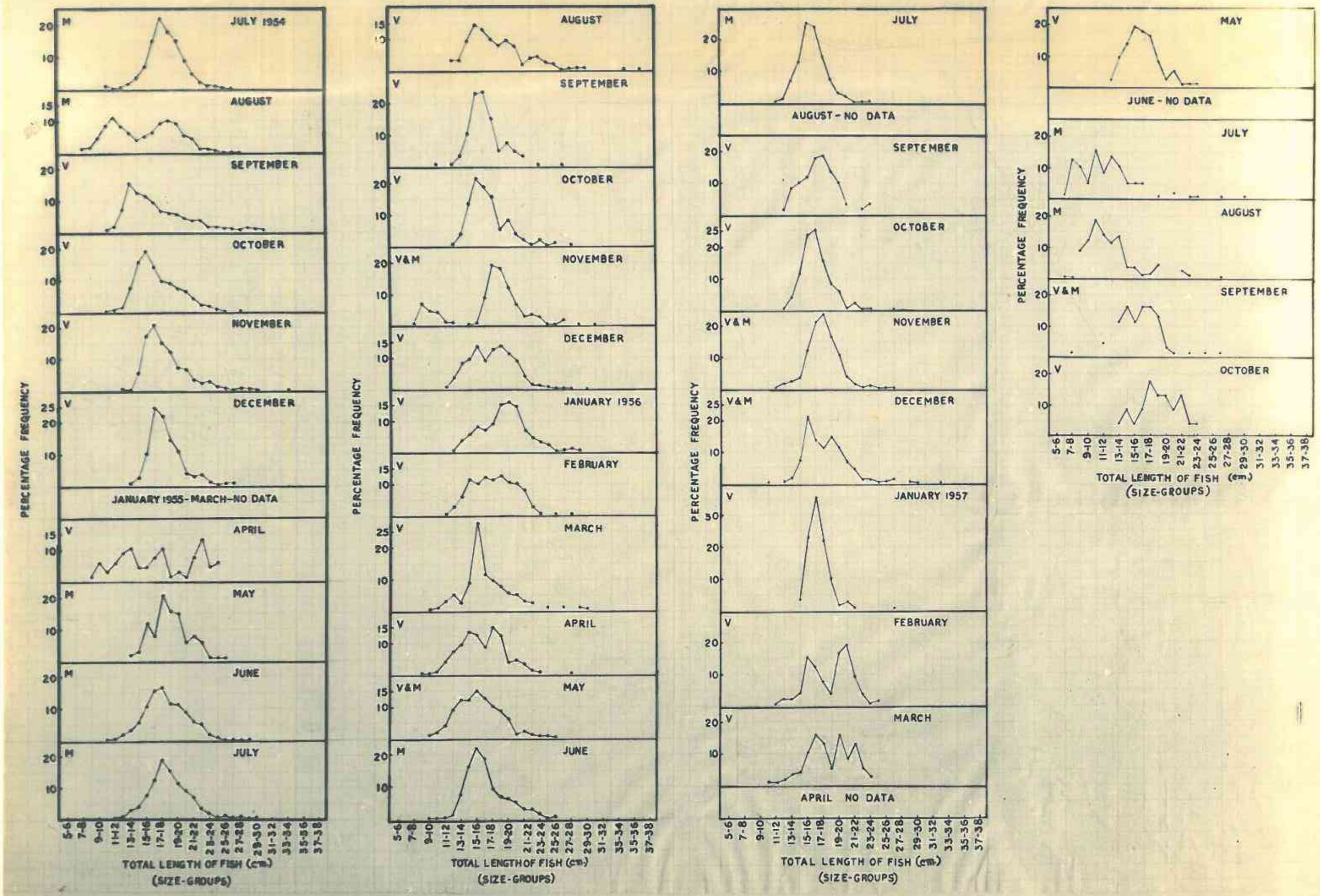

PERCENTAGE FREQUENCY
M
JULY 1954
AUGUST
V
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY 1955-MARCH-NO DATA
APRIL
MAY
JUNE
JULY
5-6
7-8
9-10
11-12
13-14
15-16
17-18
19-20
21-22
23-24
25-26
27-28
29-30
31-32
33-34
35-36
37-38
TOTAL LENGTH OF FISH (cm.)
(SIZE-GROUPS)
AUGUST
SEPTEMBER
OCTOBER
V&M
NOVEMBER
DECEMBER
JANUARY 1956
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST - NO DATA
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY 1957
FEBRUARY
MARCH
APRIL NO DATA
MAY
JUNE - NO DATA
JULY
AUGUST
SEPTEMBER
OCTOBER

Fig. 15

Hence, the data collected from the two types of gear have been pooled (Fig. 15). The salient modal values from the data collected at the two centres are given in Table XVIII. Since the modal values at the two centres are almost similar, the data from the two centres have been combined.

For a species such as P. waigiensis which spawns almost throughout the year, it is difficult to describe growth adequately by the inspection of modal progressions. For instance, during 1954 one dominant mode could be followed through the months, August to December; during 1955, few modes could be followed for short intervals of time. During the years 1956 and 1957, very few modes could be followed for short periods.

The length-frequency distributions of fish thus pooled show modes at 11.5 cm., 13.5 cm., 15.5 cm., 16.5 cm. and 16.5 cm. in August, September, October, November and December 1954 respectively. It is reasonable to assume that the modal values shown above represent one and the same brood of fish and the rate of growth during the 5 months, August to December 1954 appears to be 1 cm. per month, i.e., the growth rate after the fish enters the fishery is about 1 cm. per month. The same brood is not traceable in the fishery subsequently up to July 1955 and the mode at 23.5 cm. in August 1955 probably represents this brood, indicating a probable growth of 7 cm. during a period of 8 months - January to August 1955, a slackened growth rate of 0.87 cm. per month. Beyond August 1955,

TABLE XVIII

Modal values (gear-wise) in the length-frequency distributions of *P. waigiensis* at Vedalai (Gulf of Mannar) and Munakkad (Palk Bay) (July 1954 - October 1957)

Year and month	Centre	Modal values (cm.)		
		Gear		
		Traps	Shore seines	Combined
1954				
July	Munakkad	17.5	--	17.5
August	"	18.5	11.5; 18.5	11.5; 18.5
September	Vedalai	13.5; 22.5	12.5; 17.5	13.5
October	"	15.5	14.5	15.5
November	"	16.5; 23.5	15.5; 18.5	16.5; 23.5
December	"	16.5; 22.5	16.5; 19.5; 21.5	16.5; 22.5
1955				
January			No data	
February			No data	
March			No data	
April	"	--	9.5; 13.5; 17.5; 19.5; 22.5	9.5; 13.5; 17.5; 19.5; 22.5
May	Munakkad	15.5; 17.5; 21.5	16.5	15.5; 17.5; 21.5
June	"	17.5	--	17.5
July	"	17.5	--	17.5
August	Vedalai	15.5; 19.5; 23.0	25.0; 27.5	15.5; 19.5; 23.5
September	"	16.5; 19.5	--	16.5; 19.5
October	"	16.5; 19.5; 23.5	13.5; 15.5; 17.5; 19.5	15.5; 19.5; 23.5
November	Vedalai and Munakkad	17.5 (Vedalai)	8.5; 18.5; 23.5 (Munakkad)	8.5; 17.5 (Vedalai and Munakkad)
December	Vedalai	15.5; 18.5	15.5; 17.5; 19.5	15.5; 18.5
1956				
January	"	15.5; 19.5	--	15.5; 19.5
February	"	14.5; 16.5; 18.5	--	14.5; 16.5; 18.5
March	"	12.5; 15.5	--	12.5; 15.5
April	"	--	14.5; 17.5; 20.5	14.5; 17.5; 20.5
May	Munakkad and Vedalai	11.5; 16.5; 19.5; 21.5 (Munakkad)	13.5; 15.5 (Vedalai)	15.5; 21.5 (Munakkad and Vedalai)

Continued

TABLE XVIII (Continued)

Modal values (gear-wise) in the length-frequency distributions of *P. waigiensis* at Vedalai (Gulf of Mannar) and Munakkad (Palk Bay) (July 1954 - October 1957)

Year and month	Centre	Modal values (cm.)		
		Gear		
		Traps	Shore seines	Combined
1956				
June	Munakkad	15.5	--	15.5
July	"	15.5	--	15.5
August			No data	
September	Vedalai	17.5	--	17.5
October	"	16.5; 21.5	--	16.5; 21.5
November	Vedalai and Munakkad	17.5 (Vedalai)	15.5; 18.5; 23.5 (Munakkad)	17.5; 23.5 (Vedalai and Munakkad)
December	"	15.5; 18.5 (Vedalai)	14.5; 18.5; 21.5 (Munakkad)	15.5; 18.5 (Vedalai and Munakkad)
1957				
January	Vedalai	16.5	17.0	16.5
February	"	15.5; 20.5	--	15.5; 20.5
March	"	16.5; 19.5; 21.5	16.5	16.5; 19.5; 21.5
April			No data	
May	"	--	15.5; 20.5	15.5; 20.5
June			No data	
July	Munakkad	--	7.5; 10.5; 12.5	7.5; 10.5; 12.5
August	"	--	10.5; 13.5	10.5; 13.5
September	Vedalai and Munakkad	14.5; 16.5 (Vedalai)	17.5 (Munakkad)	14.5; 17.0 (Vedalai and Munakkad)
October	Vedalai	14.5; 17.5; 21.5	--	14.5; 17.5; 21.5

this brood is not traceable in the fishery. Since it has been found that the growth rate after the fish enters the fishery is about 1 cm. per month, it may be inferred that the size of the fish at the completion of one year may not be less than 12 cm. and is likely to be more, as the growth rate before the fish entered the fishery must have been higher. The modes at 17.5 cm. in July and 18.5 cm. in August 1954 probably represent one and the same brood showing a growth of about 1 cm. during the period. The modes at 23.5 cm. in November and 22.5 cm. in December 1954 could not be traced further.

In the year 1955, the modes at 9.5 cm., 13.5 cm., 17.5 cm., 19.5 cm. and 22.5 cm. in April, 15.5 cm., 17.5 cm. and 21.5 cm. in May, 17.5 cm. in June and 17.5 cm. in July probably represent broods liberated by individuals spawning at different intervals, the sequence of which could hardly be determined with any degree of certainty. In August, three modes were present at 15.5 cm., 19.5 cm. and 23.5 cm., of which the mode at 15.5 cm. could be identified at 16.5 cm. in September but could not be traced further; the other two modes could not be traced in the subsequent months. The mode at 19.5 cm. in September and the modes at 15.5 cm., 19.5 cm. and 23.5 cm. in October could not be traced further. In November, two modes appeared at 8.5 cm. and 17.5 cm. of which the first mode probably represents progeny liberated by spawning individuals during the preceding six months. The second

mode at 17.5 cm. could be traced at 18.5 cm. in December and 19.5 cm. in January 1956. The mode at 15.5 cm. in December could not be traced.

In the year 1956, the fishery apparently depended on a number of different modal groups in most of the months, as was the case in the years 1954 and 1955. Except for June, July and September (when only one mode was met with in each month), during the rest of the year (except August, when no data was recorded), more than one mode was met with. Of these modes, apparently the following few could be traced during the succeeding few months. In January, the mode at 15.5 cm. could be traced at 16.5 cm. in February; the mode at 14.5 cm. in February could be traced at 15.5 cm. in March and the mode at 18.5 cm. in February could be traced at 20.5 cm. in April and 21.5 cm. in May, indicating probably a growth of about 1 cm. per month; the mode at 14.5 cm. in April could be traced at 15.5 cm. in May, beyond which it could not be traced further; the mode at 16.5 cm. in October could be traced at 17.5 cm. in November and 18.5 cm. in December. The other modes at 12.5 cm. in March, 17.5 cm. in April, 15.5 cm. in June, 15.5 cm. in July, 17.5 cm. in September, 21.5 cm. in October, 23.5 cm. in November and 15.5 cm. in December had probably independent existence, being broods liberated at irregular intervals.

In the year 1957, data for the eight months,

viz., January, February, March, May, July, August, September and October were available for study. During the period, all (16.5 cm. in January, 19.5 cm. in March, 15.5 cm. and 20.5 cm. in May, 7.5 cm. and 10.5 cm. in July, 10.5 cm. in August, 17.0 cm. in September and 14.5 cm., 17.5 cm. and 21.5 cm. in October) but three modes had probably independent existence; the modes at 15.5 cm. and 20.5 cm. in February could be traced at 16.5 cm. and 21.5 cm. respectively in March and the mode at 12.5 cm. in July could be traced at 13.5 cm. in August and 14.5 cm. in September.

Since the peak spawning period of the species is during the months November and December, the average of the modal values during the three years 1954, 1955 and 1956 during these months (16.5 cm. in November and 16.5 cm. in December 1954, 17.5 cm. in November and 15.5 cm. in December 1955 and 17.5 cm. in November and 15.5 cm. in December 1956) would give the approximate size of the fish at the completion of age 1 (one year), which has been found to be 16.5 cm. A second mode was found at 23.5 cm. in November and 22.5 cm. in December 1954. In November and December 1955, no such modes were met with. In November 1956, a second mode occurred at 23.5 cm. Taking these modes as representative of two year old fish, the mean of these modes, which has been found to be 23.2 cm., may be considered as the length the fish attains at the end of the second year of life.

From the foregoing, it may be seen that most fish enter the fishery after attaining an average size of about

16.5 cm. The minimum and maximum sizes recorded during the period of this study were 10.8 cm. and 24.2 cm. respectively for males and 9.9 cm. and 37.0 cm. respectively for females. However, the smallest fish recorded, measured 3.8 cm.

Devipatnam

Fishing is carried out at Devipatnam all round the year. Length measurements of fish caught by three types of gear, viz., hooks & lines, gill nets and shore seines were available from this centre during the period October 1954-April 1956 (Table XIX). Data were first analysed gear-wise and then combined for all gear. The length-frequency curves are given in Figs. 16, 17, 18 and 19 and the salient modal values in Table XX. Out of a total period of 15 months for which the data were available, hooks & lines were operated during all the months except one, viz., November 1954; gill nets were operated only during five months, viz., October and November 1954, and April, October and November 1955; shore seines were operated during the four months, viz., August, September and October 1955 and February 1956.

The length-frequency curves of fish collected from hook & line catches (Fig. 16) show two modes at 17.5 cm., and 22.5 cm. in October 1954; during November, no catches were recorded from this gear and during December 1954 and from January to March 1955, there were no landings. In the year 1955, modes occurred at 16.5 cm. and 19.5 cm. in April, 17.5 cm. and 21.5 cm. in May, 16.5 cm. in June, 17.5 cm. in

TABLE XIX

Length-frequency distributions (gear-wise) of P. waigiensis at Devipatnam (Palk Bay)
(October 1954 - April 1956)

Size-group (cm.)	1954										1955													
	October						November		December	January, February and March	April						May		June		July	
	Hooks & lines		Gill nets		Combined		Gill nets				Hooks & lines		Gill nets		Combined		Hooks & lines		Hooks & lines		Hooks & lines	
	No.	%	No.	%	No.	%	No.	%			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
3- 4	--	--	--	--	--	--	--	--			--	--	--	--	--	--	--	--	--	--	--	--
4- 5	--	--	--	--	--	--	--	--			--	--	--	--	--	--	--	--	--	--	--	--
5- 6	--	--	--	--	--	--	--	--			--	--	--	--	--	--	--	--	1	0.1	--	--
6- 7	--	--	--	--	--	--	--	--			--	--	--	--	--	--	--	--	--	--	--	--
7- 8	--	--	--	--	--	--	--	--			--	--	--	--	--	--	--	--	--	--	--	--
8- 9	--	--	--	--	--	--	--	--			--	--	--	--	--	--	--	--	2	0.2	--	--
9-10	--	--	--	--	--	--	--	--			--	--	--	--	--	--	--	--	1	0.1	--	--
10-11	--	--	--	--	--	--	--	--			--	--	--	--	--	--	--	--	1	0.1	--	--
11-12	--	--	--	--	--	--	--	--			--	--	--	--	--	--	1	0.1	1	0.1	1	0.04
12-13	1	0.4	--	--	1	0.3	--	--			--	--	--	--	--	--	1	0.1	4	0.3	21	1.0
13-14	2	0.8	1	1.4	3	1.0	--	--			5	2.1	--	--	5	1.9	24	2.1	6	0.4	41	1.9
14-15	18	7.5	1	1.4	19	6.1	1	2.6	"	"	12	8.2	--	--	12	4.4	80	6.9	38	2.7	116	5.2
15-16	35	14.5	3	4.3	38	12.3	8	20.5	"	"	14	6.0	5	13.5	19	7.0	121	10.5	132	8.9	284	12.8
16-17	45	18.6	25	35.7	70	22.5	5	12.7	"	"	31	13.3	14	37.8	45	16.7	142	12.3	344	23.3	457	20.7
17-18	46	19.1	21	30.0	67	21.5	7	17.9	"	"	24	10.3	17	46.0	41	15.2	177	15.3	300	20.3	464	21.0
18-19	45	18.6	10	14.4	55	17.6	6	15.3	"	"	28	12.0	1	2.7	29	10.8	131	11.4	235	15.2	394	17.8
19-20	21	9.0	7	10.0	28	9.0	3	7.7			34	14.5	--	--	34	12.6	92	7.9	129	8.7	192	8.7
20-21	4	1.7	--	--	4	1.3	1	2.6			25	10.7	--	--	25	9.3	77	6.7	95	6.5	99	4.5
21-22	1	0.4	--	--	1	0.3	--	--	"	"	17	7.3	--	--	17	6.3	94	8.2	48	3.3	58	2.6
22-23	10	4.1	1	1.4	11	3.5	1	2.6			16	6.9	--	--	16	5.9	62	5.3	49	3.4	28	1.3
23-24	4	1.7	--	--	4	1.3	2	5.2	"	"	8	3.4	--	--	8	3.0	55	4.8	31	2.1	21	1.0
24-25	3	1.2	--	--	3	1.0	3	7.7			9	3.9	--	--	9	3.3	33	2.9	29	2.0	17	0.7
25-26	1	0.4	--	--	1	0.3	--	--			2	0.9	--	--	2	0.7	29	2.5	18	1.3	10	0.4
26-27	2	0.8	--	--	2	0.7	--	--			4	1.8	--	--	4	1.4	17	1.5	3	0.2	4	0.2
27-28	1	0.4	1	1.4	2	0.7	2	5.2			--	--	--	--	--	--	8	0.7	5	0.3	2	0.1
28-29	1	0.4	--	--	1	0.3	--	--			2	0.9	--	--	2	0.7	3	0.3	3	0.2	1	0.04
29-30	1	0.4	--	--	1	0.3	--	--			--	--	--	--	--	--	2	0.2	1	0.1	--	--
30-31	--	--	--	--	--	--	--	--			--	--	--	--	--	--	1	0.1	1	0.1	1	0.04
31-32	--	--	--	--	--	--	--	--			1	0.4	--	--	1	0.4	2	0.2	1	0.1	--	--
32-33	--	--	--	--	--	--	--	--			1	0.4	--	--	1	0.4	--	--	--	--	--	--
33-34	--	--	--	--	--	--	--	--			--	--	--	--	--	--	--	--	--	--	--	--
34-35	--	--	--	--	--	--	--	--			--	--	--	--	--	--	--	--	--	--	--	--
Total	241		70		311		39				233		37		270		1152		1478		2211	

Continued

TABLE XIX (Continued)

Length-frequency distributions (gear-wise) of P. waigiensis at Devipatnam (Palk Bay)
(October 1954 - April 1956)

Size-group (cm.)	1955																									
	August						September						October								November					
	Hooks & lines		Shore seines		Combined		Hooks & lines		Shore seines		Combined		Hooks & lines		Gill nets		Shore seines		Combined		Hooks & lines		Gill nets		Combined	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
3- 4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4- 5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
5- 6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
6- 7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7- 8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
8- 9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
9-10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
10-11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
11-12	--	--	1	0.2	1	0.05	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12-13	1	0.06	9	1.4	10	0.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
13-14	4	0.2	25	4.0	29	1.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
14-15	28	1.7	43	6.9	71	3.1	9	0.8	2	1.8	11	0.9	2	0.2	--	--	--	--	2	0.1	--	--	--	--	--	--
15-16	136	8.3	80	12.8	216	9.5	31	2.8	8	7.1	39	3.2	25	1.9	5	3.3	--	--	30	2.0	4	0.5	--	--	4	0.4
16-17	294	17.9	103	16.5	397	17.5	155	14.2	34	30.1	189	15.6	114	8.7	30	20.0	5	7.0	149	9.8	13	1.5	9	4.5	22	2.0
17-18	461	28.0	121	19.5	582	25.6	299	27.3	34	30.1	333	27.6	281	21.6	79	52.7	14	19.7	374	24.5	107	12.0	41	20.4	148	13.6
18-19	384	23.4	111	17.6	495	21.9	277	25.3	16	14.2	293	24.3	316	24.2	31	20.7	12	16.9	359	23.5	200	22.5	69	34.3	269	24.7
19-20	164	10.0	67	10.8	231	10.1	188	17.2	11	9.7	199	16.5	285	21.8	4	2.6	14	19.7	303	20.0	138	15.5	22	10.9	160	14.6
20-21	73	4.4	39	6.3	112	4.9	81	7.4	2	1.8	83	6.9	144	11.1	1	0.7	18	25.4	163	10.7	138	15.5	15	7.4	153	14.0
21-22	32	1.9	15	2.4	47	2.1	28	2.6	4	3.6	32	2.6	68	5.2	--	--	3	4.3	71	4.7	123	13.8	11	5.5	134	12.3
22-23	26	1.6	2	0.3	28	1.2	13	1.2	1	0.8	14	1.2	34	2.6	--	--	2	2.8	36	2.4	76	8.5	9	4.5	85	7.8
23-24	14	0.9	2	0.3	16	0.8	6	0.5	--	--	6	0.5	19	1.4	--	--	2	2.8	21	1.4	31	3.5	8	4.0	39	3.6
24-25	11	0.6	3	0.5	14	0.6	1	0.1	--	--	1	0.1	6	0.5	--	--	1	1.4	7	0.4	22	2.5	8	4.0	30	2.7
25-26	12	0.7	2	0.3	14	0.6	3	0.3	1	0.8	4	0.3	2	0.2	--	--	--	--	2	0.1	14	1.6	8	4.0	22	2.0
26-27	2	0.1	1	0.2	3	0.1	--	--	--	--	--	--	5	0.4	--	--	--	--	5	0.3	14	1.6	--	--	14	1.3
27-28	1	0.06	--	--	1	0.05	1	0.1	--	--	1	0.1	1	0.1	--	--	--	--	1	0.05	7	0.8	1	0.5	8	0.8
28-29	1	0.06	--	--	1	0.05	1	0.1	--	--	1	0.1	1	0.1	--	--	--	--	1	0.05	1	0.1	--	--	1	0.1
29-30	1	0.06	--	--	1	0.05	1	0.1	--	--	1	0.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
30-31	1	0.06	--	--	1	0.05	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	0.1	--	--	1	0.1
31-32	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
32-33	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
33-34	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
34-35	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total	1646		624		2270		1094		113		1207		1303		150		71		1524		889		201		1090	

Continued

TABLE XIX (Continued)

Length-frequency distributions (gear-wise) of P. waigiensis at Devipatnam (Palk Bay)
(October 1954 - April 1956)

Size-group (cm.)	1955		1956											
	December		January		February						March		April	
	Hooks & lines		Hooks & lines		Hooks & lines		Shore seines		Combined		Hooks & lines		Hooks & lines	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
3- 4	--	--	--	--	--	--	--	--	--	--	--	--	1	0.5
4- 5	--	--	--	--	--	--	2	4.3	2	0.5	--	--	--	--
5- 6	--	--	--	--	--	--	9	19.1	9	2.3	--	--	--	--
6- 7	--	--	--	--	--	--	8	17.1	8	2.0	--	--	--	--
7- 8	--	--	--	--	--	--	6	12.8	6	1.5	6	4.2	7	3.5
8- 9	--	--	--	--	--	--	10	21.2	10	2.6	2	1.4	--	--
9-10	1	0.1	--	--	--	--	10	21.2	10	2.6	4	2.8	4	2.0
10-11	1	0.1	--	--	2	0.6	2	4.3	4	1.0	5	3.5	2	1.0
11-12	7	1.0	--	--	4	1.2	--	--	4	1.0	7	4.8	7	3.5
12-13	6	0.9	1	0.2	5	1.4	--	--	5	1.3	7	4.8	4	2.0
13-14	15	2.2	10	2.0	19	5.5	--	--	19	4.8	7	4.8	11	5.6
14-15	18	2.6	22	4.5	27	7.8	--	--	27	6.9	3	2.1	11	5.6
15-16	13	1.9	24	4.8	11	3.2	--	--	11	2.8	3	2.1	16	8.1
16-17	16	2.3	39	7.8	13	3.8	--	--	13	3.3	3	2.1	3	1.5
17-18	17	2.5	48	9.6	13	3.8	--	--	13	3.3	11	7.6	9	4.5
18-19	21	3.1	68	13.7	22	6.4	--	--	22	5.7	11	7.6	14	7.0
19-20	41	6.0	62	12.5	52	15.0	--	--	52	13.3	15	10.4	19	9.6
20-21	67	9.8	59	11.8	58	16.8	--	--	58	14.8	10	7.0	9	4.5
21-22	118	17.2	56	11.3	49	14.2	--	--	49	12.5	7	4.9	12	6.0
22-23	111	16.2	46	9.2	33	9.6	--	--	33	8.4	18	12.5	12	6.0
23-24	76	11.1	29	5.8	13	3.8	--	--	13	3.3	8	5.6	12	6.0
24-25	47	6.9	14	2.8	7	2.0	--	--	7	1.8	7	4.8	14	7.0
25-26	35	5.0	7	1.4	2	0.6	--	--	2	0.5	2	1.4	5	2.5
26-27	20	3.0	6	1.2	8	2.3	--	--	8	2.0	--	--	11	5.6
27-28	19	2.8	2	0.4	7	2.0	--	--	7	1.8	1	0.7	7	3.5
28-29	17	2.5	1	0.2	--	--	--	--	--	--	2	1.4	3	1.5
29-30	12	1.8	4	0.8	--	--	--	--	--	--	3	2.1	3	1.5
30-31	4	0.6	--	--	--	--	--	--	--	--	2	1.4	3	1.5
31-32	2	0.3	--	--	--	--	--	--	--	--	--	--	--	--
32-33	--	--	--	--	--	--	--	--	--	--	--	--	--	--
33-34	--	--	--	--	--	--	--	--	--	--	--	--	--	--
34-35	1	0.1	--	--	--	--	--	--	--	--	--	--	--	--
Total	685		498		345		47		392		144		199	

TABLE XX

Modal values (gear-wise) in the length-frequency distributions of *P. waigiensis* at Devipatnam (Palk Bay) (October 1954 - April 1956)

Year and month	Modal values (cm.)			
	Gear			
	Hooks & lines	Gill nets	Shore seines	Combined
1954				
October	17.5; 22.5	16.5	--	16.5; 22.5
November	--	15.5; 17.5	--	15.5; 17.5
December		No data		
1955				
January		No data		
February		No data		
March		No data		
April	16.5; 19.5	17.5	--	16.5; 19.5
May	17.5; 21.5	--	--	17.5; 21.5
June	16.5	--	--	16.5
July	17.5	--	--	17.5
August	17.5	--	17.5	17.5
September	17.5	--	17.0; 21.5	17.5
October	18.5	17.5	17.5; 20.5	17.5
November	18.5	18.5	--	18.5
December	14.5; 21.5	--	--	14.5; 21.5
1956				
January	18.5	--	--	18.5
February	14.5; 20.5	--	5.5; 9.0	5.5; 9.0; 14.5; 20.5
March	12.5; 19.5; 22.5	--	--	12.5; 19.5; 22.5
April	11.5; 15.5; 19.5; 24.5; 26.5	-	--	11.5; 15.5; 19.5; 24.5; 26.5

Fig. 16. Length-frequency distributions of P. waigiensis (from hook & line landings) at Devipatnam.

(October 1954 - April 1956)

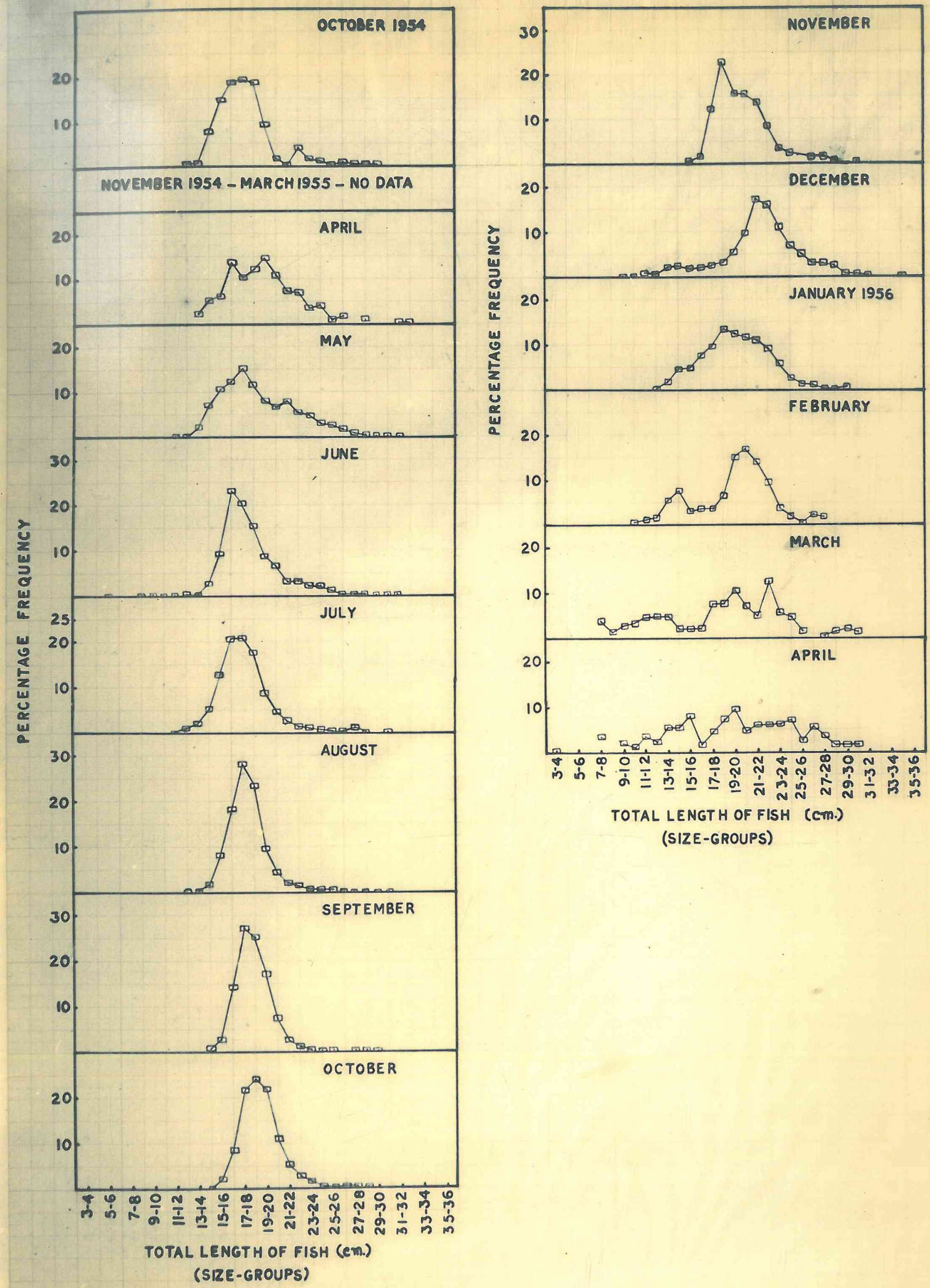

OCTOBER 1954
NOVEMBER 1954 – MARCH 1955 – NO DATA
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY 1956
FEBRUARY
MARCH
APRIL
PERCENTAGE FREQUENCY
TOTAL LENGTH OF FISH (cm.)
(SIZE-GROUPS)
3-4
5-6
7-8
9-10
11-12
13-14
15-16
17-18
19-20
21-22
23-24
25-26
27-28
29-30
31-32
33-34
35-36

Fig. 16

July, 17.5 cm. in August, 17.5 cm. in September, 18.5 cm. in October, 18.5 cm. in November and 14.5 cm. and 21.5 cm. in December. Most of these modes (except the mode at 16.5 cm. in April which could be traced at 17.5 cm. in May and the mode at 17.5 cm. in September which shifts to 18.5 cm. in October) had probably independent existence, being broods liberated at irregular intervals.

During 1956, modes appeared at 18.5 cm. in January, 14.5 cm. and 20.5 cm. in February, 12.5 cm., 19.5 cm. and 22.5 cm. in March and 11.5 cm., 15.5 cm., 19.5 cm., 24.5 cm. and 26.5 cm. in April. There does not appear to be any shift in the modal values during the four months of the year. Probably these modes too had independent existence.

The length-frequency curves of fish collected from gill net catches (Fig.17) show one mode at 16.5 cm. in October and two modes at 15.5 cm. and 17.5 cm. in November 1954, and one mode each at 17.5 cm. in April, 17.5 cm. in October and 18.5 cm. in November 1955. Due to selectivity of the gear (mesh size), the size-range of fish is limited, as indicated by the modal values. Hence, it has been felt that the gill net catches by themselves are not useful to determine the growth of fish.

The length-frequency curves of fish from shore seine catches (Fig. 18) show one mode at 17.5 cm. in August and two modes each at 17.0 cm. and 21.5 cm. in September,

Fig. 17. Length-frequency distributions of P. waigiensis (from gill net landings) at Devipatnam.

(October 1954 - November 1955)

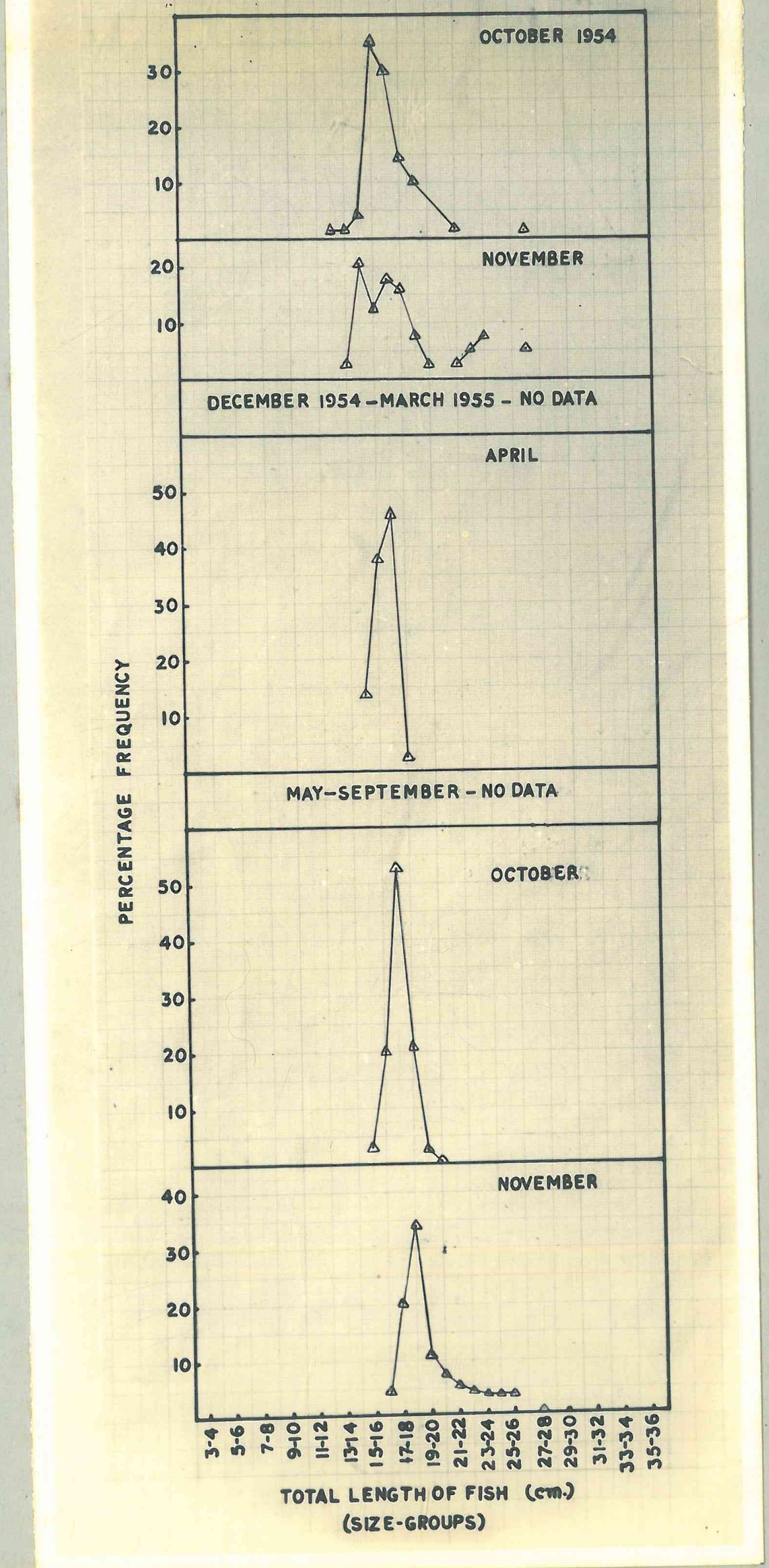

OCTOBER 1954
30
20
10
NOVEMBER
20
10
DECEMBER 1954 – MARCH 1955 – NO DATA
APRIL
50
40
30
20
10
MAY–SEPTEMBER – NO DATA
OCTOBER
50
40
30
20
10
NOVEMBER
40
30
20
10
PERCENTAGE FREQUENCY
3-4
5-6
7-8
9-10
11-12
13-14
15-16
17-18
19-20
21-22
23-24
25-26
27-28
29-30
31-32
33-34
35-36
TOTAL LENGTH OF FISH (cm.)
(SIZE-GROUPS)

Fig. 17

Fig. 18. Length-frequency distributions of P. waigiensis (from shore seine landings) at Devipatnam.

(August 1955 - February 1956)

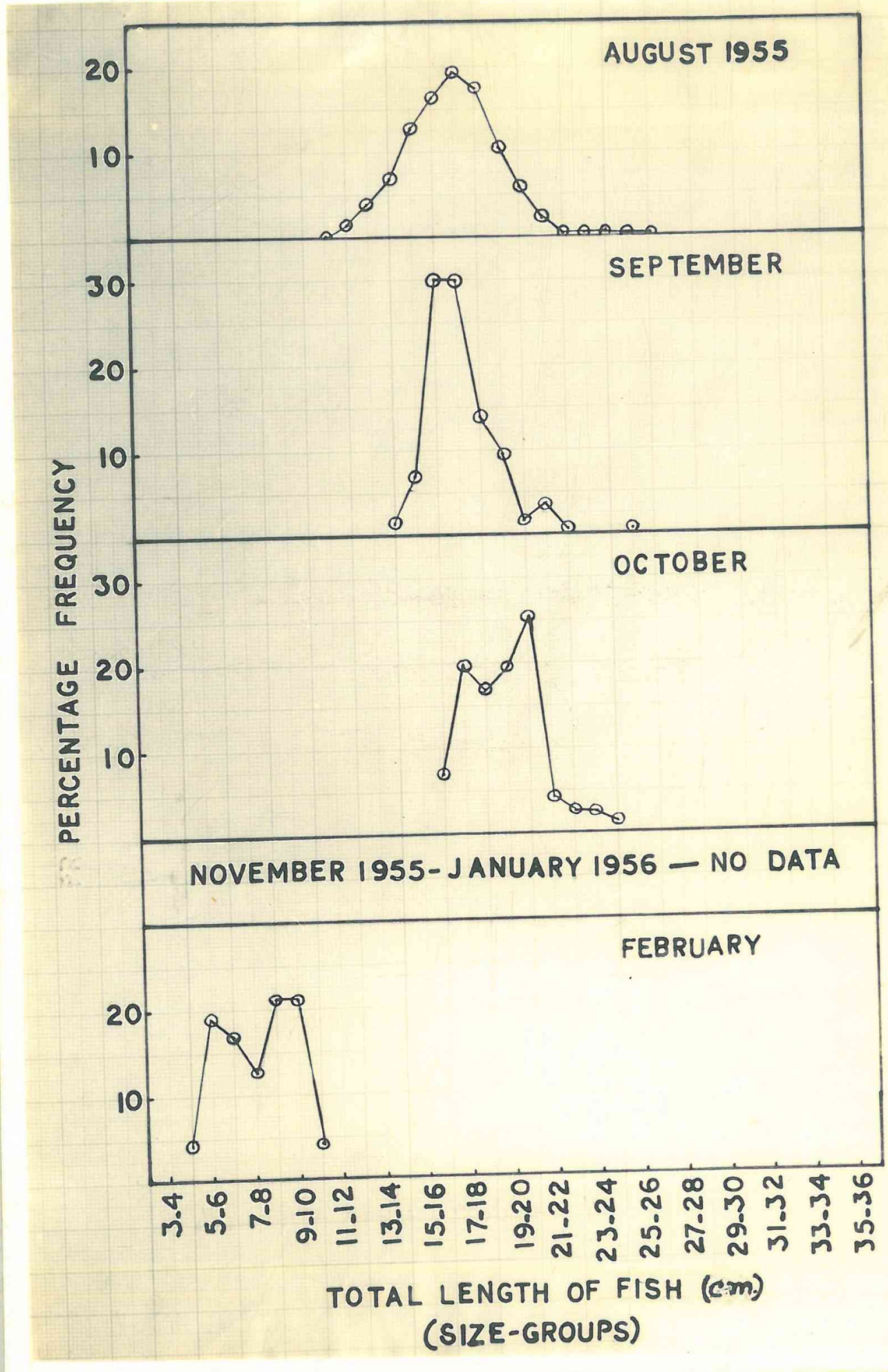

AUGUST 1955
SEPTEMBER
OCTOBER
NOVEMBER 1955- JANUARY 1956 — NO DATA
FEBRUARY
PERCENTAGE FREQUENCY
20
10
30
20
10
30
20
10
20
10
3.4
5-6
7-8
9-10
11-12
13-14
15-16
17-18
19-20
21-22
23-24
25-26
27-28
29-30
31-32
33-34
35-36
TOTAL LENGTH OF FISH (cm)
(SIZE-GROUPS)

Fig. 18

17.5 cm. and 20.5 cm. in October 1955 and 5.5 cm. and 9.0 cm. in February 1956. Shore seines being encircling drag nets, the modal values obtained from the shore seine catches represent to a greater extent the modal values of the population. However, during the three consecutive months August to October 1955, a stationary mode appeared at a size of about 17.5 cm. It is difficult to explain the modes at 21.5 cm. and 20.5 cm. in September and October 1955 respectively. The modes at 5.5 cm. and 9.0 cm. in February 1956 represent probably the broods liberated by the spawning individuals a few months earlier.

Examination of combined data (Fig. 19) at Devipatnam reveals the following features:

Two modes appeared at 16.5 cm. and 22.5 cm. in October and 15.5 cm. and 17.5 cm. in November 1954. Of these, the mode at 16.5 cm. in October could be traced at 17.5 cm. in November. In the year 1955, modes appeared at 16.5 cm. and 19.5 cm. in April, 17.5 cm. and 21.5 cm. in May, 16.5 cm. in June, 17.5 cm. each in July, August, September and October, 18.5 cm. in November and 14.5 cm. and 21.5 cm. in December. Most of these modes had had probably independent existence, except modes at 16.5 cm. in April (which could be traced at 17.5 cm. in May), 16.5 cm. in June (which could be traced at 17.5 cm. in July) and 17.5 cm. in October (which could be traced at 18.5 cm. in November). In the year 1956, modes appeared at 18.5 cm. in January, 5.5 cm.,

Fig. 19. Length-frequency distributions of P. waigiensis (combined data) at Devipatnam. (October 1954 - April 1956)

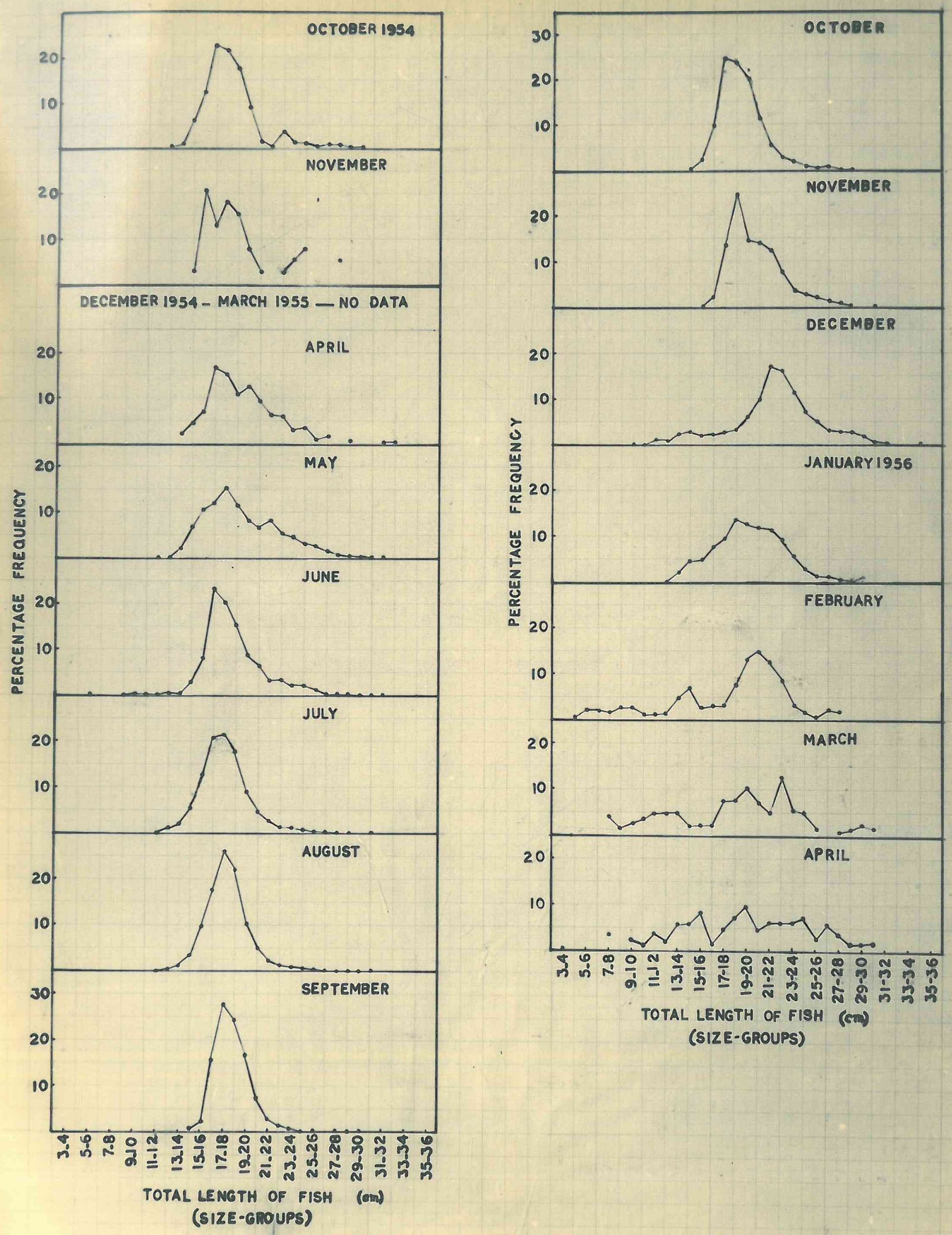

OCTOBER 1954
NOVEMBER
DECEMBER 1954 – MARCH 1955 — NO DATA
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY 1956
FEBRUARY
MARCH
APRIL
PERCENTAGE FREQUENCY
10
20
30
3.4
5-6
7.8
9-10
11-12
13-14
15-16
17-18
19-20
21-22
23-24
25-26
27-28
29-30
31-32
33-34
35-36
TOTAL LENGTH OF FISH (cm)
(SIZE-GROUPS)

Fig. 19

9.0 cm., 14.5 cm. and 20.5 cm. in February, 12.5 cm., 19.5 cm. and 22.5 cm. in March and 11.5 cm., 15.5 cm., 19.5 cm., 24.5 cm. and 26.5 cm. in April.

The gear-wise and combined data reveal predominantly stationary modes in the length-frequency distributions at Devipatnam. Few modes show negligible shifts through short intervals of time. Hence, it is difficult to demarcate age-groups from the modal values, much less assess the rates of growth of fish from this centre. Young ones were met with in many months indicating prolonged recruitment to the stock.

Tondi

Fishing is carried out at Tondi all round the year. Data collected during the period October 1955-June 1956 from gill net and shore seine catches are given in Table XXI and the salient modal values in Table XXII. The length-frequency curves are given in Figs. 20, 21 and 22.

Gill net catches (Fig.20) were available only during October and November 1955, the modal values in the respective months being 17.5 cm. and 17.5 cm.

Shore seine catches (Fig. 21) were available throughout the period of study. The length-frequency curves show two modes at 13.5 cm. and 15.5 cm. in October and three modes at 13.5 cm., 17.5 cm. and 20.5 cm. in November 1955. None of these could be traced subsequently. Combined frequency

TABLE XXI

Length-frequency distributions (gear-wise) of P. waigiensis at Tondi (Palk Bay)
(October 1955 - June 1956)

Size-group (cm.)	1955 October Gill nets No.	1955 October Gill nets %	1955 October Shore seines No.	1955 October Shore seines %	1955 October Combined No.	1955 October Combined %	1955 November Gill nets No.	1955 November Gill nets %	1955 November Shore seines No.	1955 November Shore seines %	1955 November Combined No.	1955 November Combined %	1955 December	1956 January Shore seines No.	1956 January Shore seines %	1956 February Shore seines No.	1956 February Shore seines %	1956 March Shore seines No.	1956 March Shore seines %	1956 April and May	1956 June Shore seines No.	1956 June Shore seines %
6- 7	--	--	--	--	--	--	--	--	--	--	--	--		1	0.3	1	0.3	--	--		--	--
7- 8	--	--	--	--	--	--	--	--	--	--	--	--		5	1.5	1	0.3	--	--		--	--
8- 9	--	--	--	--	--	--	--	--	--	--	--	--		10	3.0	6	2.0	--	--		--	--
9-10	--	--	--	--	--	--	--	--	--	--	--	--		7	2.1	14	4.5	1	0.8		1	0.5
10-11	--	--	--	--	--	--	--	--	--	--	--	--		27	8.0	19	6.2	8	6.5		3	1.4
11-12	--	--	6	3.1	6	1.7	--	--	2	2.5	2	0.3		24	7.1	25	8.1	12	9.8		6	2.8
12-13	--	--	12	6.1	12	3.4	--	--	2	2.5	2	0.3		35	10.3	23	7.4	17	14.0		2	0.9
13-14	1	0.7	36	18.4	37	10.6	3	0.5	4	5.1	7	0.9		40	11.8	32	10.4	20	16.4		10	4.6
14-15	1	0.7	34	17.4	35	10.0	41	6.5	2	2.5	43	6.0		36	10.6	30	9.7	9	7.4		13	6.0
15-16	13	8.4	48	24.5	61	17.4	148	23.3	7	8.9	155	21.7		24	7.1	26	8.4	13	10.7		22	10.2
16-17	38	24.7	28	14.3	66	18.9	156	24.6	11	13.9	167	23.4		24	7.1	21	7.0	10	8.1		21	9.7
17-18	42	27.3	12	6.1	54	15.5	159	25.1	15	19.0	174	24.4		17	5.0	11	3.6	2	1.6		20	9.3
18-19	39	25.3	5	2.6	44	12.6	77	12.1	13	16.5	90	12.6		28	8.2	22	7.1	4	3.3		18	8.3
19-20	11	7.1	1	0.5	12	3.4	42	6.6	8	10.0	50	7.0		23	6.8	17	5.5	9	7.4		28	13.0
20-21	5	3.2	--	--	5	1.4	4	0.6	9	11.4	13	1.8		15	4.4	16	5.2	4	3.3		15	6.9
21-22	2	1.3	3	1.5	5	1.4	2	0.3	3	3.8	5	0.7		7	2.0	8	2.6	3	2.5		10	4.6
22-23	--	--	4	2.0	4	1.1	--	--	1	1.3	1	0.2		5	1.5	17	5.5	1	0.8		12	5.6
23-24	2	1.3	2	1.0	4	1.1	--	--	--	--	--	--		9	2.6	8	2.6	3	2.5		12	5.6
24-25	--	--	3	1.5	3	0.9	1	0.2	1	1.3	2	0.3		2	0.6	3	0.9	3	2.5		5	2.3
25-26	--	--	--	--	--	--	--	--	1	1.3	1	0.2		--	--	3	0.9	--	--		10	4.6
26-27	--	--	2	1.0	2	0.6	1	0.2	--	--	1	0.2		--	--	3	0.9	1	0.8		1	0.5
27-28	--	--	--	--	--	--	--	--	--	--	--	--		--	--	1	0.3	1	0.8		3	1.4
28-29	--	--	--	--	--	--	--	--	--	--	--	--		--	--	--	--	--	--		--	--
29-30	--	--	--	--	--	--	--	--	--	--	--	--		--	--	--	--	1	0.8		2	0.9
30-31	--	--	--	--	--	--	--	--	--	--	--	--		--	--	1	0.3	--	--		--	--
31-32	--	--	--	--	--	--	--	--	--	--	--	--		--	--	1	0.3	--	--		2	0.9
Total	154		196		350		634		79		713			339		309		122			216	

TABLE XXII

Modal values (gear-wise) in the length-frequency distributions of P. waigiensis at Tondi (Palk Bay) (October 1955 - June 1956)

Year and month	Modal values (cm.)		
	Gear		
	Gill nets	Shore seines	Combined
1955			
October	17.5	13.5; 15.5	13.5; 16.5
November	17.5	13.5; 17.5; 20.5	17.5
December		No data	
1956			
January	--	8.5; 10.5; 13.5; 18.5; 23.5	8.5; 10.5; 13.5; 18.5; 23.5
February	--	11.5; 13.5; 18.5; 22.5	11.5; 13.5; 18.5; 22.5
March	--	13.5; 15.5; 19.5	13.5; 15.5; 19.5
April		No data	
May		No data	
June	--	11.5; 15.5; 19.5; 23.0; 25.5	11.5; 15.5; 19.5; 23.0; 25.5

Fig. 20. Length-frequency distributions of P. waigiensis (from gill net landings) at Tondi.
(October - November 1955)

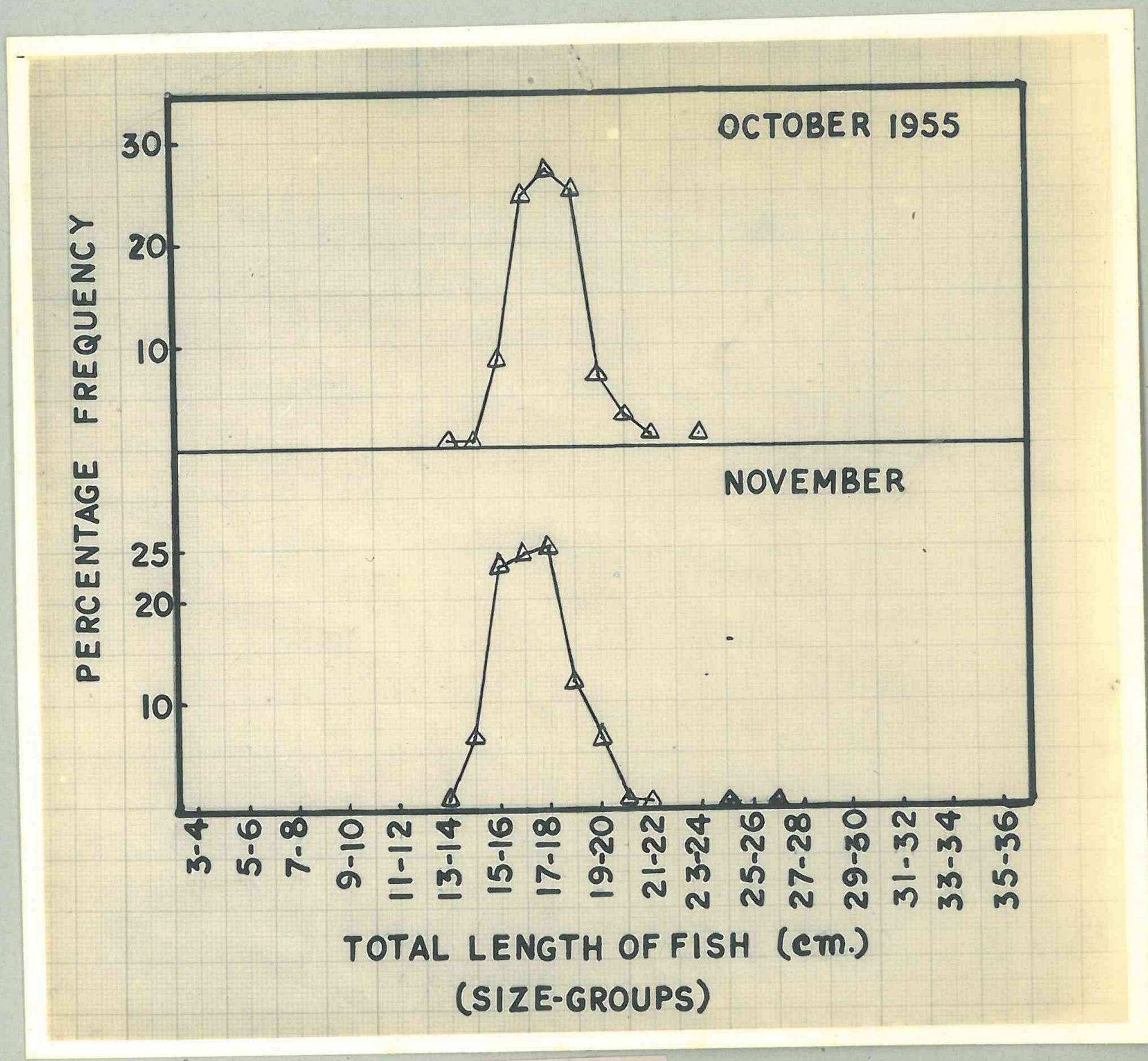

OCTOBER 1955
30
20
10
NOVEMBER
25
20
10
PERCENTAGE FREQUENCY
3-4
5-6
7-8
9-10
11-12
13-14
15-16
17-18
19-20
21-22
23-24
25-26
27-28
29-30
31-32
33-34
35-36
TOTAL LENGTH OF FISH (cm.)
(SIZE-GROUPS)

Fig. 20

Fig. 21. Length-frequency distributions of P. waigiensis (from shore seine landings) at Tondi.
(October 1955 - June 1956)

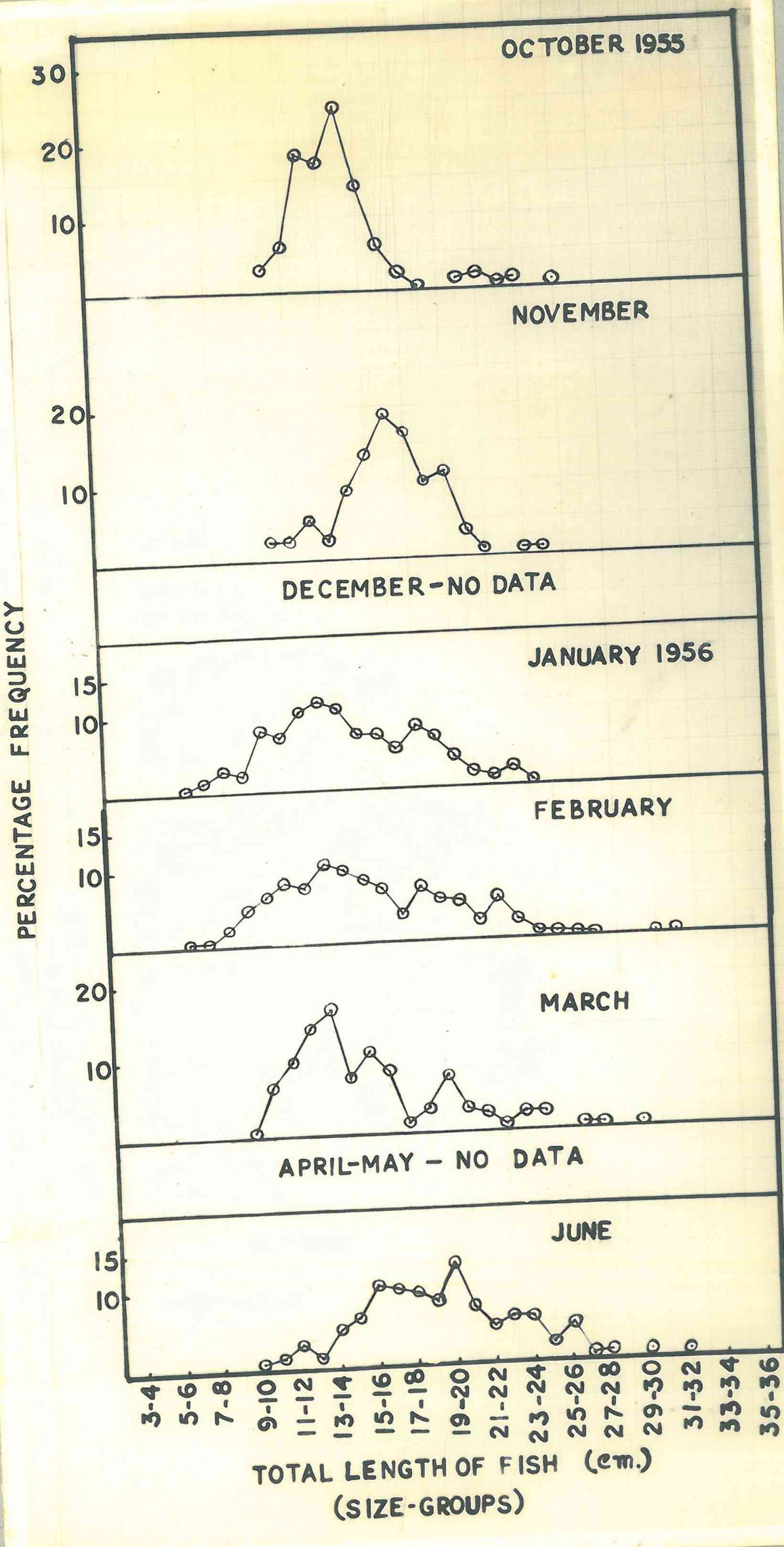

OCTOBER 1955
30
20
10
NOVEMBER
20
10
DECEMBER - NO DATA
JANUARY 1956
15
10
FEBRUARY
15
10
MARCH
20
10
APRIL-MAY - NO DATA
JUNE
15
10
PERCENTAGE FREQUENCY
3-4
5-6
7-8
9-10
11-12
13-14
15-16
17-18
19-20
21-22
23-24
25-26
27-28
29-30
31-32
33-34
35-36
TOTAL LENGTH OF FISH (cm.)
(SIZE-GROUPS)

Fig. 21

curves (Fig. 22) show modes at 13.5 cm. and 16.5 cm. in October and 17.5 cm. in November 1955. The mode at 16.5 cm. in October shifts to 17.5 cm. in November 1955, indicating growth of 1 cm. During the year 1956, only shore seines were operated. In January, five modes appeared at 8.5 cm., 10.5 cm., 13.5 cm., 18.5 cm. and 23.5 cm. In February, four modes appeared at 11.5 cm., 13.5 cm., 18.5 cm. and 22.5 cm. In March, three modes appeared at 13.5 cm., 15.5 cm. and 19.5 cm., and in June, five modes appeared at 11.5 cm., 15.5 cm., 19.5 cm., 23.0 cm. and 25.5 cm. Of these, only two modes could be traced in the subsequent months - the mode at 10.5 cm. in January shifts to 11.5 cm. in February and the mode at 18.5 cm. in February shifts to 19.5 cm. in March.

While the data from gill net catches are limited, the modes from shore seine catches could be traced for limited periods only. Therefore, these data have also not been useful in the study of age and growth of the species.

Taking the overall picture into consideration, it may be seen that the modes are stable over several months. Such stability of modes may probably mainly be due to two factors. 1. selectivity of the gear; 2. fish of a particular size may enter the shallow fishing areas and leave them on attaining a larger size.

Fig. 22. Length-frequency distributions of P. waigiensi
(combined data) at Tondi.
(October 1955 - June 1956)

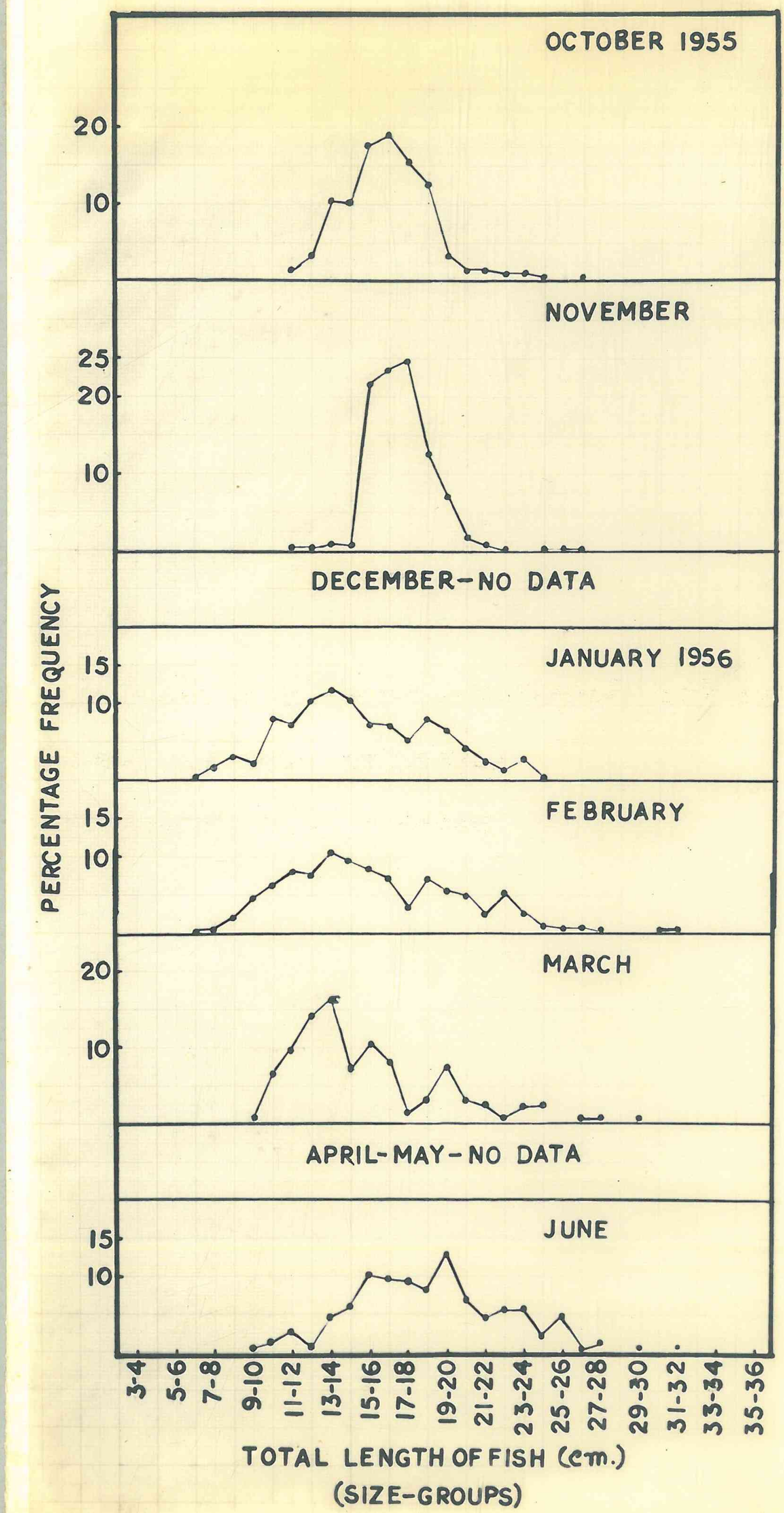

OCTOBER 1955
20
10
NOVEMBER
25
20
10
DECEMBER-NO DATA
JANUARY 1956
15
10
FEBRUARY
15
10
MARCH
20
10
APRIL-MAY-NO DATA
JUNE
15
10
PERCENTAGE FREQUENCY
3-4
5-6
7-8
9-10
11-12
13-14
15-16
17-18
19-20
21-22
23-24
25-26
27-28
29-30
31-32
33-34
35-36
TOTAL LENGTH OF FISH (cm.)
(SIZE-GROUPS)

Fig. 22

ii. Skeletal structures

Most of the earlier works deal with studies on scales and otoliths of fishes living under temperate conditions, where the seasons are well marked. In the tropics, the variations in temperature are reduced to a minimum and the two extremes of winter and summer of the temperate regions are not to be found.

Van Oosten (1929) gave a detailed review of the scale method. Chugunov (1926), as referred to by Menon (1950a) gave a detailed survey of the literature (mainly by Russian workers) on age determination by bones. Graham (1929) made an elaborate survey of several papers on age determination of fishes by the use of scales, otoliths and other bones. Menon (op. cit.) reviewed literature on the use of bones other than otoliths in determining the age and gro th rate of fishes. Amongst other references on the subject mention may be made of Hickling (1933), Le Cren (1947), Jones and Hynes (1950), Bowers (1954), Qasim (1957) and Kelley and Wolf (1959).

However, some work has been done in the past on the otoliths and scales of fishes living under tropical conditions. In India, Hornell and Nayudu (1923) noticed growth rings on the scales and Nair (1949) observed rings on the otoliths of Sardinella longiceps. The latter opined that the rings are formed annually due to scarcity of planktonic food. Seshappa and Bhimachar (1951, 1954 and 1955) studied the scales of Cynoglossus semifasciatus and opined that the

rings are formed once a year, during the South West monsoon, owing to the scarcity of the food organisms. Prabhu (1953) studied the scales and otoliths of Chirocentrus dorab and observed distinct rings on them. He did not indicate any definite causative factor for the formation of these rings. Amongst other works on the subject, mention may also be made of those of Radhakrishnan (1954, 1957) on the otoliths of Sillago sihama, Sarojini (1957) on the scales of Mugil parsia, Pillay (1958) on the scales of Hilsa ilisha, Seshappa (1958) on the scales of Rastrelliger kanagurta, Rao (1961) on the scales and otoliths of Pseudosciaena diacanthus and Kutty (1961) on the scales and otoliths of Otolithoides brunneus. Several suggestions and reasons have been given by the above authors for the formation of seasonal marks on the otoliths and scales of the fishes mentioned.

A. Otoliths

Of the three otoliths, sagitta is the largest and is the one that has been commonly used for age determination in fishes. In P. waigiensis, the sagitta is oblong in shape with a bifid anterior end. The concave side has a deep notch in the centre. In large individuals, the edge of sagitta shows crenulations at the posterior end. Otoliths from fresh specimens have been used in the present studies; those from formalin-preserved specimens do not show the marks clearly. The alternating bands on the otoliths have been variously termed by different authors light and dark, opaque and transparent,

white and translucent, etc. In the present investigation, the terms opaque and translucent are used to denote the growth zone and growth check respectively. Examination of the right and left otoliths gave similar results. The nucleus in all otoliths is translucent surrounding which an opaque zone is invariably present. A varying number of translucent rings depending upon the size of fish could be seen outside this opaque zone, the rings and zones regularly alternating with each other. Translucent rings are counted from the nucleus towards the periphery of the otolith, irrespective of whether the last ring is at the edge of the otolith or is bounded by an opaque zone. False rings are discontinuous and could be distinguished from true rings which are continuous.

Otoliths from 605 fish have been examined for direct reading of the number of translucent rings. Of these, 63 pairs of otoliths have been utilised for detailed measurements of radii of rings for purpose of back-calculation of age of fish. Otoliths have been examined in xylol and alcohol, of which the former gave better results. Hence, in this study, xylol has been used as the medium.

Direct reading of otoliths

Particulars of the number of rings on otoliths in relation to size of fish are given in Table XXIII. It may be seen from the table that out of a total of 605 otoliths, 224 otoliths did not show any rings, 331 showed only one ring,

TABLE XXIII

Direct reading of otoliths of P. waigiensis

Size-group (Total length cm.)	Mid-point of size-group	No. of fish	No. of rings on otoliths				
			0	1	2	3	4
8-10	9	1	1	-	-	-	-
10-12	11	17	17	-	-	-	-
12-14	13	70	68	2	-	-	-
14-16	15	107	74	33	-	-	-
16-18	17	147	19	128	-	-	-
18-20	19	115	15	98	2	-	-
20-22	21	29	14	53	2	-	-
22-24	23	34	12	14	8	-	-
24-26	25	19	2	2	15	-	-
26-28	27	15	2	1	11	1	-
28-30	29	5	-	-	1	4	-
30-32	31	2	-	-	-	2	-
32-34	33	2	-	-	-	2	-
34-36	35	1	-	-	-	-	1
36-38	37	1	-	-	-	-	1
Total		605	224	331	39	9	2
Mean size of fish (cm.)			18.34	24.74	30.11	36.00	

39 showed two rings, 9 showed three rings and 2 showed four rings. Fish below 12.0 cm. in length had no rings on their otoliths.

Otoliths with one ring (Photograph 8) were found in fish ranging in size from 12.0 cm. to 28.0 cm.; otoliths with two rings (Photograph 9) were found in fish ranging in size from 18.0 cm. to 30.0 cm.; otoliths with three rings (Photograph 10) were found in fish ranging in size from 26.0 cm. to 34.0 cm.; and otoliths with four rings (Photograph 11) were found in fish ranging in size from 34.0 cm. to 38.0 cm. The mean size of fish with one, two, three and four rings on otoliths is indicated at the bottom of Table XXIII. The results are summarised in Table XXIV.

TABLE XXIV

Summary of direct reading of otoliths of P. waigiensis

Age	No. of fish	Size-range (cm.)	Mean length (cm.)	Growth increment (cm.)
1+	331	12 - 28	18.34	
2+	39	18 - 30	24.74	6.40
3+	9	26 - 34	30.11	5.37
4+	2	34 - 38	36.00	5.89

From the length-frequency study, it has been

Photograph 8. Left otolith from fish, 17.5 cm.
dated 26-7-1954 showing one ring; x 10.0.
(material used as negative)

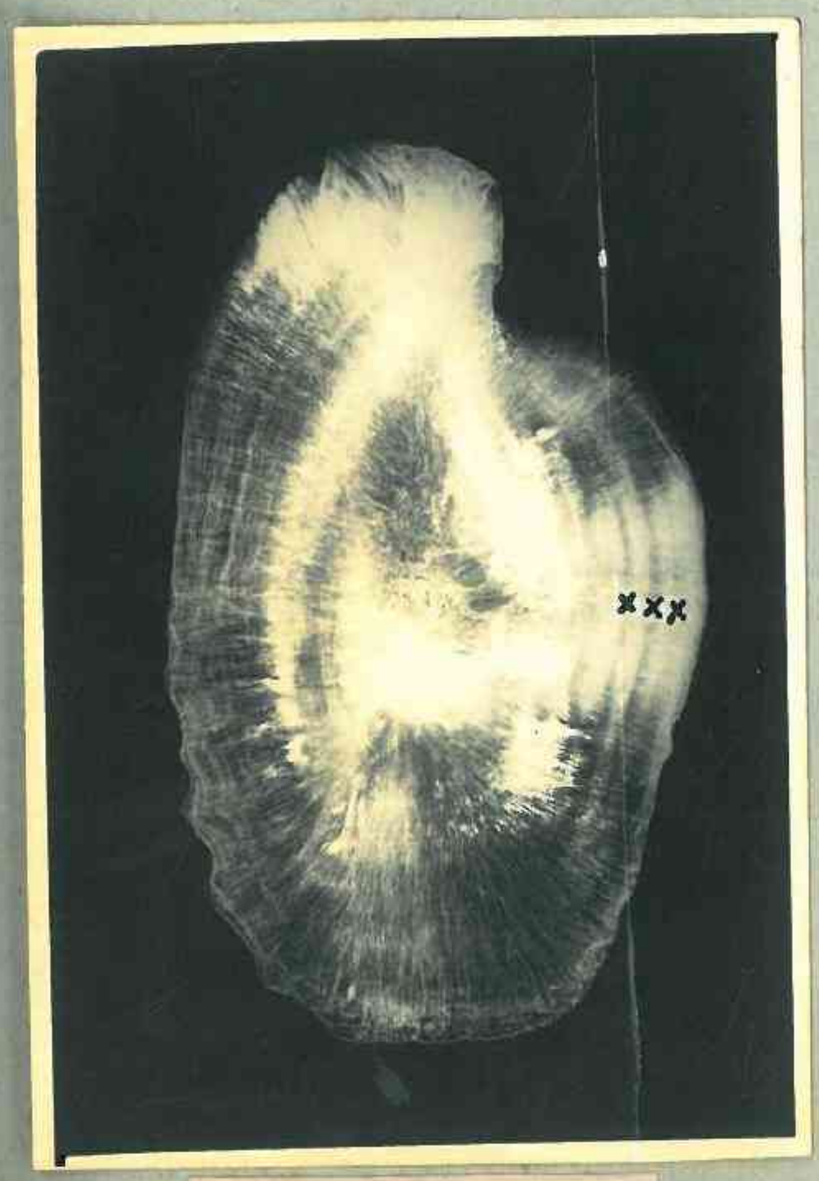
Photograph 9. Right otolith from fish, 23.1 cm.
dated 16-8-1955 showing two rings; x 8.9.
(material used as negative)

Photograph 10. Left otolith from fish, 28.5 cm.
dated 15-9-1954 showing three rings; x 7.9.
(material used as negative)

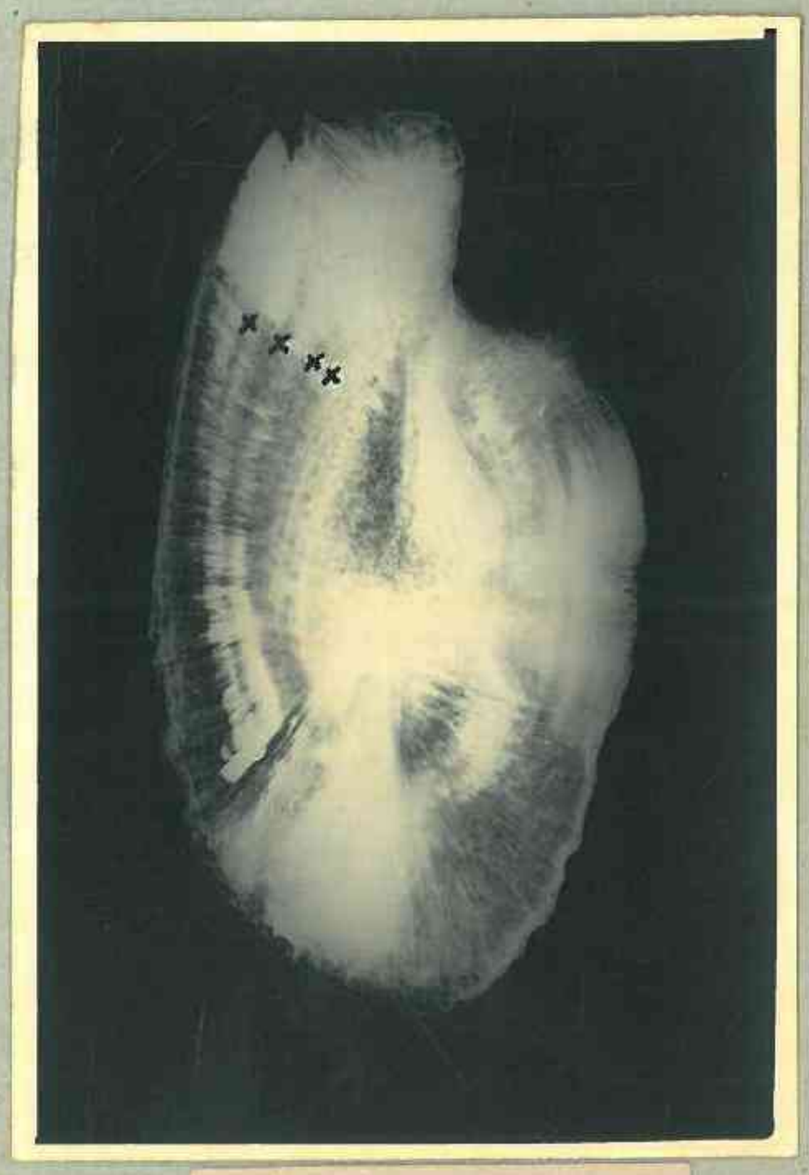
Photograph 11. Left otolith from fish, 35.2 cm.
dated 27-12-1955 showing four rings; x 6.0.
(material used as negative)

Photograph 8

Photograph 9



Photograph 10



Photograph 11

(Rings marked x)

found that the fish attains a mean size of 16.5 cm. at the end of the first year and about 23.2 cm. at the end of the second year of its life. The mean size of the fish having otoliths with one and two rings as given at the bottom of Table XXIII agrees fairly well with the above observations. This indicates that the rings on otoliths are annual in nature and may be helpful in determining the age of individual fish.

Back-calculation of age of fish from otoliths

If the ring in otoliths is annual in nature, a fish having otoliths with r rings will be more than r years old but less than r + 1 years old. Thus, a gross mean size of fishes having otoliths with one, two, three and four rings will not give the accurate mean size of fish but only the approximate size when a fish is one, two, three and four years old respectively. Therefore, the back-calculation method has been employed to arrive at the precise size of fish during successive years of its life.

The success of back-calculation depends on the type of relationship between the length of the fish and the length of the otolith. For an effective back-calculation of the size of the fish at the completion of a particular age, it is first necessary to suppose that the growth of a fish and the growth of its otolith are related in some easily calculable way. Generally, it has been supposed that the growth of a fish and its otolith are proportionally or

linearly related. The relationship between fish length and otolith length has been determined for a few species (Hickling, 1933; Saetersdal, 1953). Fry (1943) has considered a relationship of the form $y = bx^n$ for several species of fish from scale measurements. Sheriff (1922) attempted to show that a parabolic fish length/scale length relationship was more appropriate than a linear one in the herring.

When the fish length/otolith length relationship is proportional, the length of a fish at some previous age (t) is given by:

$$Lt = \frac{Lr_t}{R}$$

where L and R are the total length of fish and total radius of otolith respectively, L_t is the calculated total length of fish at age t and r_t is the radius of otolith up to the t^{th} ring.

If the relationship is of the form $L = a + bR$, errors in calculating the intermediate lengths will arise using the simple proportionality formula and the true values are given by a different expression of the form:

$$L_t = L\frac{r_t}{R} + a\left(1-\frac{r_t}{R}\right)$$

In these cases, the errors in the values of intermediate lengths obtained from the proportionality formula, will depend on the magnitude of the second term in the expression

given above, and this will increase in size/age of the fish. If the relationship is curvilinear, a more complex expression will follow.

For the species under study, a scatter diagram showing the total length of fish along the Y-axis and the total radius of otolith along the X-axis is given in Fig.23. The relationship is obviously linear of the type:

$$L = a + bR$$

where a and b are parameters whose estimates are to be obtained from the data.

The least square estimates of a and b are given by:

$$b = \frac{\Sigma LR - \frac{\Sigma L \Sigma R}{n}}{\Sigma R^2 - \frac{(\Sigma R)^2}{n}} \quad \text{and}$$

$$a = \bar{L} - b\bar{R}$$

The sums of L, R and sums of R^2 and products of L and R are given below:

N	ΣL	ΣR	ΣLR	ΣR^2	$\bar{L}$	$\bar{R}$
202	3565.7	6531.0	121085.5	219843.0	17.6520	32.3317

From the above, the least square estimates of a and b are obtained as:

Fig. 23. Relation between otolith radius and length of fish.

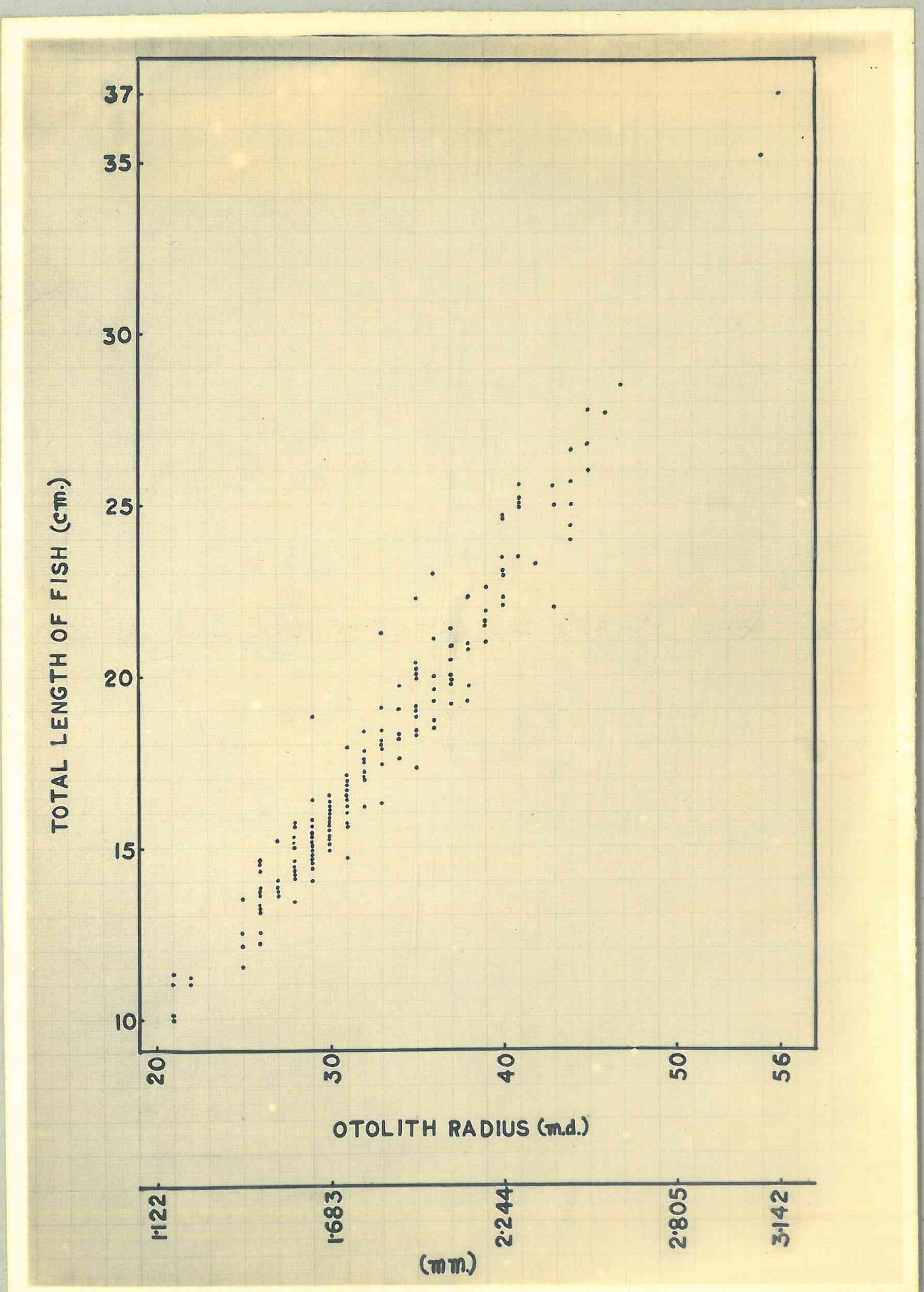

TOTAL LENGTH OF FISH (cm.)
37
35
30
25
20
15
10
20
30
40
50
56
OTOLITH RADIUS (m.d.)
1·122
1·683
2·244
2·805
3·142
(mm.)

Fig. 23

$$a = -3.9423$$

$$b = 0.6679$$

so that the relation between L and R is

$$L = -3.9423 + 0.6679R$$

Using this formula, the length of the fish at the completion of the t^{th} ring is given by:

$$L_t = a + br_t$$

where r_t = radius of otolith up to the t^{th} ring.

This equation can be rewritten as:

$$L_t = L\frac{r_t}{R} + a(1 - \frac{r_t}{R})$$

Using the formula given above, the back-calculated lengths of fish at completed ages (L_1, L_2, L_3, L_4 at the completion of 1, 2, 3, 4 years respectively) for a sample of 63 fish were obtained and presented in Table XXV. The results are summarised below:

Back-calculated length of fish	Mean size (cm.)	Growth Increment (cm.)
L_1	14.50	
L_2	20.77	6.27
L_3	26.16	5.39
L_4	29.97	3.81

TABLE XXV

Back-calculation of length of *P. waigiensis*

Sl. No.	Total length of fish (cm.)	Total radius of otolith R (m.d.)	Radius of otolith up to the ring (m.d.)				Back-calculated length of fish (cm.)			
			r_1	r_2	r_3	r_4	L_1	L_2	L_3	L_4
1	37.0	56	26	35	43	48	15.07	21.65	27.49	31.15
2	35.2	55	25	35	42	46	13.85	20.97	25.95	28.79
3	28.5	47	26	37	42	--	14.01	21.60	25.05	--
4	27.8	45	28	37	--	--	15.81	22.16	--	--
5	27.7	46	26	35	--	--	13.92	20.14	--	--
6	26.8	45	25	35	--	--	13.14	19.96	--	--
7	26.6	44	25	36	--	--	13.41	21.04	--	--
8	26.0	45	30	38	--	--	16.02	21.35	--	--
9	25.7	44	28	36	---	--	14.92	20.31	--	--
10.	25.6	43	25	35	--	--	13.23	20.11	--	--
11.	25.6	41	26	36	--	--	14.79	22.00	--	--
12	25.2	41	28	34	--	--	15.96	20.23	--	--
13	25.1	41	26	36	--	--	14.48	21.56	--	--
14	25.0	41	26	36	14.41	--	14.41	21.47	--	--
15	25.0	43	28	38	--	--	14.90	21.63	--	--
16	25.0	44	32	37	--	--	17.10	20.39	--	--
17	14.7	40	25	36	--	--	13.96	21.84	--	--
18	24.6	40	26	34	--	--	14.61	20.32	--	--
19	24.5	41	26	34	--	--	14.10	19.65	--	--
20	24.4	44	34	--	--	--	17.96	--	--	--
21	23.5	40	28	35	--	--	15.27	20.07	--	--
22	23.3	42	26	35	--	--	12.92	18.76	--	--
23	23.1	40	28	36	--	--	14.99	20.40	--	--

Continued

TABLE XXV (Continued)

Back-calculation of length of P. waigiensis

Sl. No.	Total length of fish (cm.)	Total radius of otolith R (m.d.)	Radius of otolith upto to the ring (m.d.)				Back-calculated length of fish (cm.)			
			r_1	r_2	r_3	r_4	L_1	L_2	L_3	L_4
24	23.0	36	24	32	--	--	14.02	20.00	--	--
25	23.0	40	30	--	--	--	16.27	--	--	--
26	22.6	39	29	--	--	--	16.05	--	--	--
27	22.0	43	33	--	--	--	15.96	--	--	--
28	21.9	39	29	--	--	--	15.27	--	--	--
29	21.6	39	29	--	--	--	15.01	--	--	--
30	21.4	37	24	--	--	--	12.49	--	--	--
31	21.1	36	25	--	--	--	13.45	--	--	--
32	21.0	39	28	--	--	--	13.88	--	--	--
33	21.0	39	30	--	--	--	15.24	--	--	--
34	20.8	38	30	--	--	--	15.59	--	--	--
35	20.5	37	30	--	--	--	15.37	--	--	--
36	20.4	35	28	--	--	--	15.57	--	--	--
37	20.1	35	27	--	--	--	14.61	--	--	--
38	20.1	35	26	--	--	--	13.92	--	--	--
39	20.0	37	32	--	--	--	16.77	--	--	--
40	20.0	35	28	--	--	--	15.25	--	--	--
41	20.0	36	29	--	--	--	15.34	--	--	--
42	19.9	37	30	--	--	--	15.39	--	--	--
43	19.8	37	27	--	--	--	13.38	--	--	--
44	19.6	36	28	--	--	--	14.36	--	--	--
45	19.3	36	28	--	--	--	14.13	--	--	--
46	19.3	38	30	--	--	--	14.41	--	--	--
47	19.2	37	30	--	--	--	14.82	--	--	--

Continued

TABLE XXV (Continued)

Back-calculation of length of P. waigiensis

Sl. No.	Total length of fish (cm.)	Total radius of otolith R (m.d.)	Radius of otolith up to the ring (m.d.) r_1	r_2	r_3	r_4	Back-calculated length of fish (cm.) l_1	l_2	l_3	l_4
48	19.1	33	25	--	--	--	13.51	--	--	--
49	18.8	35	28	--	--	--	14.25	--	--	--
50	18.5	36	30	--	--	--	14.76	--	--	--
51	18.4	36	23	--	--	--	12.12	--	--	--
52	18.4	35	30	---	--	--	15.21	--	--	--
53	18.4	33	26	--	--	--	13.66	--	--	--
54	18.3	35	30	--	--	--	15.13	--	--	--
55	18.2	34	26	--	--	--	12.99	--	--	--
56	18.1	33	26	--	--	--	13.42	--	--	--
57	18.0	33	27	--	--	--	14.01	--	--	--
58	17.9	31	25	--	--	--	13.68	--	--	--
59	17.5	32	26	--	--	--	13.48	--	--	--
60	17.3	35	30	--	--	--	13.27	--	--	--
61	16.0	31	25	--	--	--	12.14	---	--	--
62	15.7	30	26	--	--	--	13.08	--	--	--
63	15.6	29	25	--	--	--	12.91	--	--	--
Mean			27.54	35.57	42.33	47.00	14.50	20.77	26.16	29.97

Scale for otolith readings: 1 ocular micrometer division = 56.1 μ
= 0.0561 mm.

m.d. = micrometer division.

Growth equation

Several authors have attempted to describe the varying growth rates at successive age intervals by a single growth equation. The most successful and widely used growth equation is the von Bertalanffy growth equation (von Bertalanffy, 1934, 1938, 1949) which may be written as:

$$Lt = L\infty \left\{1-e^{-K(t - t_o)}\right\}$$

where L_t = length of the fish at age t

$L\infty$ = asymptotic length of the fish

K = coefficient of growth

t_o = an adjustment in the time axis when the theoretical length of the fish is equal to zero.

The equation can also be rewritten as:

$$L_{t+1} = a + bL_t$$

where $b = e^{-K}$ and

$$L\infty = \frac{a}{1-b}$$

Using the mean values of sizes obtained from back-calculated lengths from otolith readings and using the rewritten von Bertalanffy equation and assuming the size of the fish as zero at zero age, the least square estimates of a and b have been found to be:

$a = 13.8244$

$b = 0.5877$

which gives $L\infty = 33.5300$ and

$K = 0.5317$

The estimated size of the fish at successive ages calculated from the von Bertalanffy equation is given below along with the mean values obtained (back-calculated lengths) from the otolith readings (Table XXV):

Age	Mean calculated size (cm.)	Estimated size from the growth equation (cm.)
1	14.50	13.74
2	20.77	21.79
3	26.16	26.82
4	29.97	29.51

A close agreement between the two could be noticed; therefore, the fitted von Bertalanffy growth equation (Fig.24) adequately describes the growth of the fish.

B. Scales

The scales of P. waigiensis are ctenoid showing variations in different regions of the body. The scales in the area covered by the tip of the pectoral fin in its natural position show a high degree of constancy as regards the sculptural details and relative size. Scales from this region were taken for study. Regenerated scales, characterised by a pebbly area near the centre (Carlander, 1950), and which can easily be recognised by naked eye, were

Fig. 24. Growth curve of P. waigiensis.

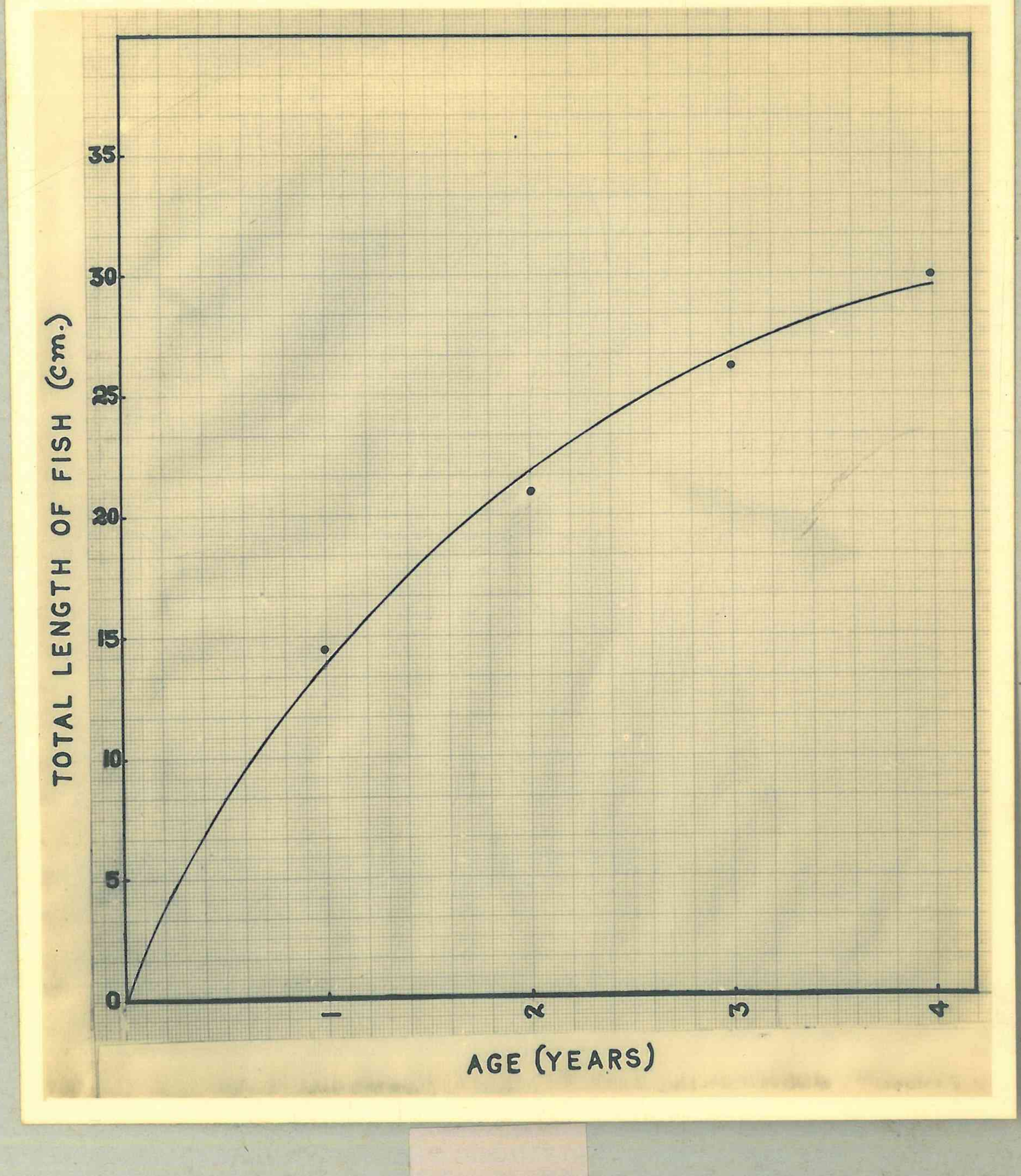


Fig. 24

discarded.

Scales from 197 fish have been examined, but only eight fish in the size-group 28.0 cm.-37.0 cm. have shown the formation of rings (characterised by sclerites becoming narrow and the intervals between preceding and succeeding sclerites getting closed up), the number of which has been found inconsistent in relation to length of fish. Since fish with such scales constitute a negligible percentage of the sample, it has not been possible to study in detail the utility of such marks in the determination of age of fish.

Summarising the observations on length-frequency distribution and the otoliths, it may be seen that the results arrived at independently by these two methods are generally in agreement and the lengths arrived at from the growth equation at different ages may be considered more precise.

CHAPTER 4

FOOD AND FEEDING HABITS

The importance of the study of food and feeding habits of commercially important fishes is well known. The earliest works from India on this subject include those of Hornell and Naidu (1923) and Devanesan (1932) who worked on the food of *Sardinella longiceps* and *S. gibbosa* respectively and Sen (1937), Hora and Nair (1938) and Roy (1938) who worked on the food of certain larvicidal fishes. Job (1940) gave for the first time a detailed account of the nutrition of the Madras perches which deserves special mention in this connection. Chacko (1949) gave an account of the food of some perches from the Gulf of Mannar. Mookerjee, Ganguly and Mazumdar (1946) studied the food of the estuarine fishes of Bengal. Menon (1948) studied the food of the bekti, *Lates calcarifer* from Bengal. Since no information on the food of *P. waigiensis* is available, a detailed study has been undertaken.

The stomach contents were analysed both qualitatively and quantitatively. The 'Points Method' of Swynnerton and Worthington (1940), as modified by Frost (1943), has been adopted in the present investigation with slight modifications. This is essentially a volumetric method, in that, while allotting points, the volume of each food component was estimated by eye

judgment and the degree of fullness of the stomachs was also taken into consideration.

To test the efficacy of this method, a set of 50 stomachs collected at Tondi in June 1956 were analysed first by the 'Points Method' and later by the 'Volumetric Method'. The results are presented in Table XXVI. It may be seen that both methods yield almost similar results but since the 'Points Method' involves less time, it has been adopted in this study.

Points were allotted to the stomach in the first instance, depending upon the degree of fullness of the stomach, as modified by Frost (1943), irrespective of the size of the fish. While allotting points, the amount of food contained in each stomach was also given due consideration. The estimation of the total volume of food contained in the stomach as well as the individual volumes of different items was done by eye judgment. In all, fish have been classified into eight size-groups with a class interval of 5 cm, e.g., 0-5 cm., 5-10 cm. and so on. Depending upon the degree of fullness, the stomachs have been grouped as gorged (30 points), full (20 points), 3/4 full (15 points), 1/2 full (10 points), 1/4 full (5 points), almost empty (1-4 points) and empty. The almost empty stomach may contain a few remnants of highly macerated food items, whereas an empty stomach contains no trace of food items.

TABLE XXVI

Analysis of stomach contents of P. waigiensis from Tondi
by Points Method and Volumetric Method
(June 1956)

No. of fish examined		No. of empty stomachs	Total points/c.c gained by all fish	
Males	Females		points	c.c.
20	30	8	249	31.5

Continued

Percentage composition of food components												
Teleostean fishes		Crabs		Prawns				Stomatopods		Other items	
				Penaeid		Carid					
P.M.	V.M.	P.M.	V.M.	P.M.	V.M.	P.M.	V.M.	P.M.	V.M.	P.M.	V.M.
1.6	2.5	16.5	19.0	61.1	53.7	18.9	21.6	1.9	3.2	--	--

P.M. = Points Method

V.M. = Volumetric Method

i. Qualitative analysis

For this study, fish from all the centres have been considered together, in order to give a gross picture of the diet. Food items met with in the stomachs of 1069 fish analysed from the four centres are given. Where food species were in an identifiable condition, the identifications were made up to the species. More often than not, the food items were found in a mutilated condition, where it has been possible to identify them only to generic or family level, as the case may be.

The main food of the fish consists of crabs and prawns belonging to certain families. Crabs were represented by the families Portunidae (genera Portunus, Charybdis and Thalamita), Leucosiidae (genus Philyra), Maiidae (genera Tylocarcinus and Schizophrys) and Xanthidae (genus Menippe). Prawns could be identified broadly as penaeid and carid prawns. Penaeid prawns were represented by Penaeus monodon and Metapenaeus monoceros and carid prawns by the families Processidae and Alphaeidae.

Young ones of teleostean fishes of the following thirteen genera were met with in the stomach contents: Lutianus, Gerres, Caranx, Allanetta, Gobiodon, Cynoglossus, Lethrinus, Siganus, Therapon, Leiognathus, Triacanthus, Platycephalus and Epinephelus. Whenever it was not possible to identify, fishes have been grouped as 'teleostean fish remains'.

Isopods were represented by the genus Cynodoce belonging to the family Sphaeromidae. Stomatopods were represented by the genus Squilla. Amphipods were met with as food items only occasionally, gastropods were represented by the six genera Oliva, Cerithium, Turritella, Littorina, Nerita and Natica and pelecypods were met with rarely, as only fragments of bivalve shells were found in quite few stomachs. Cephalopods were represented by Sepia. A few polychaete worms were found occasionally in some stomachs.

Sea grass of the genera Cymodocea and Halophila were found occasionally in a few stomachs along with sand and clumps of mud. Algae of the genera Hypnea, Spyridea, Gracilaria, Roschera, Sargassum, Neomeris and Acetabularia were also present occasionally. These are considered as items of food in view of their repeated occurrence.

From the above observations, it may be surmised that P. waigiensis is an omnivore with certain browsing habits.

A study of the fauna and flora of fishing grounds of P. waigiensis (vide v, correlation between the stomach contents and their occurrence in the environment) has revealed that a close correlation exists between the food items and the habitat.

ii. Quantitative analysis

The stomach contents of P. waigiensis from Vedalai, Munnakkad, Devipatnam and Tondi have been analysed month-wise and presented in Tables XXVII, XXVIII, XXIX and XXX.

Vedalai

Data collected for a period of 13 months - August to December 1955, April and May 1956, January to May and December 1957 from this centre are available for study. Details are given in Table XXVII.

Crabs

Crabs formed 100 per cent of the food in October 1955 and they were at their lowest in February 1957, when they were only 22.9 per cent of the total food components. Crabs constituted the dominant item of food during all the other months.

Prawns

Prawns occurred as the dominant item of food of the fish during February 1957, when they constituted 47.9 per cent of the food. During the other months, except November 1955 and April and May 1957, prawns were second (next to crabs) in the order of abundance. Prawns formed 17.9 per cent of the total food in November 1955. During April and May 1957, prawns constituted 13.3 per cent

TABLE XXVII

Percentage composition of food items of P. waigiensis at Vedalai

(August 1955 - December 1957)

Year and month	No. of fish examined	Items of food						
		Crabs	Prawns	Teleostean fishes	Isopods	Molluscs	Sea grass and algae	Sand and mud
1955								
August	2	60.0	40.0	--	--	--	--	--
September	5	82.8	14.3	--	--	--	2.9	--
October	6	100.0	--	--	--	--	--	--
November	12	64.2	17.9	--	--	--	17.9	--
December	27	77.2	8.2	7.0	1.9	0.6	5.1	--
1956								
January to March				No data				
April	37	42.7	37.7	14.6	--	1.6	3.4	--
May	33	63.2	21.3	8.0	--	1.7	5.8	--
June to December				No data				
1957								
January	23	42.9	38.5	11.0	3.3	--	4.3	--
February	11	22.9	47.9	15.6	6.3	--	7.3	--
March	18	59.7	28.9	3.0	1.2	0.6	6.6	--
April	1	46.7	13.3	26.7	--	--	13.3	--
May	45	75.9	7.5	2.3	--	4.1	9.8	0.4
June to November				No data				
December	1	--	--	--	--	--	--	--

and 7.5 per cent of the food. Prawns were not met with in any of the stomachs in October 1955.

Teleostean fishes

Teleostean fishes were absent from the stomach contents during the period August to November 1955 and December 1957 (only one fish recorded had an empty stomach). They ranked third in the order of abundance during December 1955, April and May 1956 and January and February 1957, when they formed 7.0 per cent, 14.6 per cent, 8.0 per cent, 11.0 per cent and 15.6 per cent respectively of the total food consumed. They occurred to the extent of 3.0 per cent of the food in March, 26.7 per cent in April when they ranked second in the order of abundance and 2.3 per cent in May 1957.

Isopods.

Isopods occurred only during December 1955 and January to March 1957 forming 1.9 per cent, 3.3 per cent, 6.3 per cent and 1.2 per cent respectively of the total food consumed. Obviously, isopods do not constitute an important item of the food.

Molluscs

Molluscs occurred smarcely during December 1955, April and May 1956 and March and May 1957, with a minimum of 0.6 per cent in December 1955 and a maximum of

4.1 per cent in May 1957. This group is therefore not considered an important item of food.

Sea grass and algae

During August and October 1955, sea grass and algae were totally absent from the stomach contents. Their occurrence ranged from a minimum of 2.9 per cent in September to a maximum of 17.9 per cent of the food in November 1955. During September 1955 and March and April 1957, they ranked third in the order of abundance. In May 1957, they ranked second. From the foregoing, it may be surmised that sea grass and algae constitute an important item of food of the fish.

Sand and mud

Sand and other inorganic matter may be considered as accidental inclusions in the stomach contents, owing to the browsing habits of the fish. These occurred only to the extent of 0.4 per cent in May 1957.

Munakkad

Data collected for a period of 7 months - July and August 1955, November and December 1956 and July, August and September 1957 from this centre are available for study. Details are given in Table XXVIII. The salient features of the composition of food of the fish from this centre are the preponderance of prawns

TABLE XXVIII

Percentage composition of food items of P. waigiensis at Munakkad (July 1955 - September 1957)

Year and month	No. of fish examined	Items of food							
		Crabs	Prawns	Teleostean fishes	Isopods	Stomatopods	Amphipods	Molluscs	Sea grass and algae
1955									
July	33	43.4	38.6	12.0	--	--	--	6.0	--
August	12	28.0	50.0	13.1	--	--	--	0.9	7.5
September to December				No data					
1956									
January to October				No data					
November	53	26.4	50.8	2.0	16.4	1.4	1.6	0.4	1.0
December	1	--	--	--	--	--	--	--	--
1957									
January to June				No data					
July	44	3.6	65.4	7.2	18.2	--	3.0	1.2	1.4
August	14	--	61.0	13.6	23.6	--	--	1.8	--
September	27	6.8	78.0	2.2	11.3	--	--	1.4	0.3

over crabs and the occurrence of stomatopods and amphipods.

Crabs

Crabs predominated in July 1955, when they formed 43.4 per cent of the food. They were absent from the stomach contents in December 1956 (only one fish recorded had an empty stomach) and August 1957. The minimum percentage (3.6) of crabs was recorded in July 1957. Crabs ranked second in the order of abundance during August 1955 and November 1956, when they constituted 28.0 per cent and 26.4 per cent of the food respectively. In September 1957, they ranked third (6.8 per cent) amongst the food components.

Prawns

Prawns occurred as the dominant food during the entire period except July 1955. Their occurrence ranged from 38.6 per cent in July 1955 to 78.0 per cent in September 1957.

Teleostean fishes

Teleostean fishes occurred amongst the food components during all the months except December 1956 (only one fish recorded had an empty stomach). Their occurrence ranged from a minimum of 2.0 per cent in November 1956 to a maximum of 13.6 per cent in August 1957. In the latter month they ranked third in importance amongst the

food components. The importance of teleostean fishes as food can be gauged from the fact that they occurred third in the order of abundance during July and August 1955 and July and August 1957.

Isopods

Isopods constituted a sizable part of the food, as evidenced by their occurrence to the extent of 16.4 per cent in November 1956, 18.2 per cent in July, 23.6 per cent in August and 11.3 per cent of the food in September 1957. During November 1956, they ranked third in the order of abundance and in July, August and September 1957, they ranked second. During the other months, they were totally absent from the stomachs.

Stomatopods

Stomatopods occurred as food only during November 1956 to the extent of 1.4 per cent.

Amphipods

Amphipods occurred as food only during November 1956 and July 1957 to the extent of 1.6 per cent and 3.0 per cent.

Molluscs

Molluscs occurred as food during all the months except December 1956 (only one fish recorded had an empty stomach). Their occurrence ranged from a minimum

of 0.4 per cent in November 1956 to a maximum of 6.0 per cent in July 1955. This group did not form an important item of food.

Sea grass and algae

Sea grass and algae formed the food of the fish during August 1955, November 1956 and July and September 1957 to the extent of 7.5 per cent, 1.0 per cent, 1.4 per cent and 0.3 per cent respectively.

Devipatnam

Data collected for a period of 9 months - September 1955 to May 1956 are available for study from this centre. Details are given in Table XXIX.

Crabs

Crabs occurred as food during all the months except February 1956. Their occurrence ranged from a minimum of 0.5 per cent in March 1956 to a maximum of 88.6 per cent in May 1956. They ranked second in the order of abundance during September, October and November 1955, when they formed 32.0 per cent, 22.9 per cent and 36.7 per cent of the food respectively. During December 1955 and January 1956, they ranked third forming as much as 10.2 per cent and 9.4 per cent respectively of the total food consumed. They formed the dominant food (60.0 per cent) in April 1956.

TABLE XXIX

Percentage composition of food items of P. waigiensis at Devipatnam
(September 1955 - May 1956)

Year and month	No. of fish examined	Items of food								
		Crabs	Prawns	Teleostean fishes	Isopods	Stomatopods	Molluscs	Polychaetes	Sea grass and algae	Sand and mud
1955										
September	45	32.0	41.7	2.6	23.5	--	--	--	0.2	--
October	55	22.9	50.9	5.2	17.3	1.5	--	1.1	1.1	--
November	51	36.7	44.9	3.1	6.0	6.9	--	--	2.4	--
December	50	10.2	61.8	27.0	--	--	--	--	1.0	--
1956										
January	35	9.4	69.8	20.8	--	--	--	--	--	--
February	39	--	85.5	12.8	0.7	--	--	--	1.0	--
March	45	0.5	88.8	8.6	--	--	1.3	--	0.8	--
April	4	60.0	22.2	--	--	--	4.4	--	6.7	6.7
May	7	88.6	7.1	--	--	2.9	--	--	1.4	--

Prawns

Prawns occurred as the main constituent of the food during the period September 1955 to March 1956. Their occurrence ranged from a minimum of 7.1 per cent in May to a maximum of 88.8 per cent in March 1956. In April, they occurred to the extent of 22.2 per cent of the food, being second in the order of abundance.

Teleostean fishes

Teleostean fishes occurred during all but two months - April and May 1956. Their occurrence ranged from a minimum of 2.6 per cent in September to a maximum of 27.0 per cent in December 1955. In December 1955, they ranked as the second important food. They ranked as the second important food during the succeeding months - January, February and March 1956 when they occurred to the extent of 20.8 per cent, 12.8 per cent and 8.6 per cent respectively.

Isopods

Isopods occurred only during September, October and November 1955 and February 1956 to the extent of 23.5 per cent, 17.3 per cent, 6.0 per cent and 0.7 per cent respectively. During September and October 1955, they were third in the order of abundance. They ranked fourth in abundance during November 1955.

Stomatopods

Stomatopods occurred only during October

and November 1955 and May 1956 to the extent of 1.5 per cent, 6.9 per cent and 2.9 per cent respectively. During the latter two months, they formed the third important food item.

Molluscs

Molluscs were present in the food only in March and April 1956 constituting 1.3 per cent and 4.4 per cent respectively.

Polychaetes

Polychaetes occurred as food only during October 1955, forming 11 per cent of the total food consumed.

Sea grass and algae

Sea grass and algae occurred as food during all but one month - January 1956. Their occurrence ranged from a minimum of 0.2 per cent in September 1955 to a maximum of 6.7 per cent in April 1956; during the latter month, they were the third important food item.

Sand and mud

Sand and other inorganic matter occurred as accidental inclusions only in April 1956, forming 6.7 per cent of the stomach contents.

Tondi

Data collected for a period of 7 months -

September to November 1955, January to March and June 1956 are available for study from this centre. Details are given in Table XXX.

Crabs

Crabs occurred as food during all the months except January 1956. Their occurrence ranged from a minimum of 1.9 per cent each in November 1955 and February 1956 to a maximum of 23.5 per cent in March 1956. In the latter month, they were the second important food item. In September 1955, they ranked second in the order of abundance, occurring to the extent of 10.4 per cent. In October 1955, they occurred to the extent of 2.1 per cent of the food, being the third important food item. In June 1956, crabs were second in the order of abundance, forming 16.5 per cent of the food.

Prawns

Prawns formed the main item of food during the entire period. Their occurrence ranged from a minimum of 69.6 per cent in March 1956 to a maximum of 94.7 per cent in October 1955.

Teleostean fishes

Teleostean fishes were found only during September 1955 and January, February and June 1956 when they constituted 5.9 per cent, 6.8 per cent, 5.1 per cent

TABLE XXX

Percentage composition of food items of P. waigiensis at Tondi
(September 1955 - June 1956)

Year and month	No. of fish examined	Items of food							
		Crabs	Prawns	Teleostean fishes	Isopods	Stomatopods	Molluscs	Sea grass and algae	Sand and mud
1955									
September	11	10.4	78.5	5.9	5.2	--	--	--	--
October	37	2.1	94.7	--	2.8	--	--	0.4	--
November	46	1.9	88.5	--	9.4	--	--	0.2	--
December	No data								
1956									
January	50	--	93.2	6.8	--	--	--	--	--
February	50	1.9	92.2	5.1	0.6	--	0.2	--	--
March	39	23.5	69.6	--	2.8	1.7	1.7	--	0.7
April and May	No data								
June	50	16.5	80.0	1.6	--	1.9	--	--	--

and 1.6 per cent of the food respectively. In September 1955, they were the third important food item. During January and February 1956, they formed the second abundant item of food.

Isopods

Isopods formed food of the fish during September to November 1955 and February and March 1956. During September 1955, they were the fourth important item of food occurring to the extent of 5.2 per cent. They were the second important food item in October 1955 when they formed 2.8 per cent of the food. In November 1955, they were second in the order of abundance, occurring to the extent of 9.4 per cent of the food. In February 1956, they occurred only to the extent of 0.6 per cent and in March 1956, they were the third important food item occurring to the extent of 2.8 per cent.

Stomatopods

Stomatopods occurred in the stomach contents only during March and June 1956 to the extent of 1.7 per cent and 1.9 per cent respectively. They were fourth in the order of abundance in March and third in June 1956.

Molluscs

Molluscs formed food of the fish in February and March 1956 when they constituted 0.2 per cent and 1.7 per cent of the food respectively.

Sea grass and algae

Sea grass and algae were present in the stomach contents only in October and November 1955 when they formed 0.4 per cent and 0.2 per cent of the food.

Sand and mud

Sand and other inorganic matter occurred as accidental inclusions only in March 1956 to the extent of 0.7 per cent.

Taking the entire period as a whole, the quantitative analysis of different food items from the four centres (Table XXXI) suggests the following general conclusions:

Crabs were the most important item of food at Vedalai, whereas prawns were the most important in the diet at Tondi; at Devipatnam and Munakkad too, prawns were relatively more important in the diet. Teleostean fishes constituted the maximum percentage of the food at Devipatnam. The other items of importance in the food were isopods, which were maximum at Munakkad and sea grass and algae, which were maximum at Vedalai. Other items of food mentioned in the quantitative analysis of the food at the four centres do not generally constitute any significant portion of the food.

TABLE XXXI

Summary of analysis of stomach contents of P. waigiensis from various centres by Points Method (1955 - 1957)

Centre	Total no. of fish examined	No. of empty stomachs (%)	Total points gained by all stomachs	Average points gained by each stomach	Percentage composition of food components									
					Crabs	Prawns	Teleostean fishes	Isopods	Stomatopods	Amphipods	Molluscs	Polychaetes	Sea grass and algae	Sand and mud
Vedalai	221	61 (27.6)	1353	8.5	61.1	22.8	7.4	1.0	--	--	1.5	--	6.1	0.1
Munakkad	184	34 (18.5)	1594	10.6	14.1	61.5	5.8	14.2	0.4	1.4	1.3	--	1.3	--
Devipatnam	381	76 (19.9)	3088	10.1	18.6	60.8	10.3	7.4	1.3	--	0.2	0.2	1.1	0.1
Tondi	283	24 (8.5)	2398	9.3	6.2	87.4	2.6	3.0	0.4	--	0.2	--	0.1	0.1

Comparison of the analysis of stomach contents by 'Points Method' and 'Dominance Method'

The results arrived at by the 'Points Method' have been compared with those arrived at by using the 'Dominance Method', where the percentages of different food items have been calculated for the entire period based on their frequency of occurrence as dominant food in the total number of stomachs examined. The comparison shows that both the methods yield almost similar results (Tables XXXI and XXXII).

iii. Feeding intensity

In order to find out the variation in feeding intensity month-wise at each of the four centres, average values of volume of stomach contents (based on the 'Points Method') have been obtained by dividing the total volume (points) gained by all stomachs by the total number of stomachs that contributed to this volume. Empty stomachs have been excluded from this calculation, but their incidence has been indicated separately. The details for each centre, (Vedalai, Munakkad, Devipatnam and Tondi) are given separately in Tables XXXIII, XXXIV, XXXV and XXXVI.

At Vedalai (Table XXXIII), the average feeding intensity during the period August 1955-December 1957 has been found out to be 9.6. Feeding intensity values during September and December 1955, April 1956 and

TABLE XXXII

Summary of analysis of stomach contents of P. waigiensis from various centres by Dominance Method (1955 - 1957)

Centre	Total No. of fish examined	No. of empty stomachs	Number of stomachs containing the following food components as dominant food stuff (expressed as percentage)									
			Crabs	Prawns	Teleostean fishes	Isopods	Stomatopods	Amphipods	Molluscs	Polychaetes	Sea grass and algae	Sand and mud
Vedalai	221	61	100 (62.5)	39 (24.3)	12 (7.5)	2 (1.3)	--	--	--	--	5 (3.1)	2 (1.3)
Munakkad	184	34	21 (14.0)	99 (66.0)	7 (4.6)	20 (13.3)	1 (0.7)	2 (1.4)	--	--	--	--
Devipatnam	381	76	52 (17.0)	188 (61.6)	34 (11.1)	26 (8.5)	2 (0.7)	--	--	1 (0.4)	2 (0.7)	--
Tondi	283	24	18 (6.9)	228 (88.0)	9 (3.5)	2 (0.8)	2 (0.8)	--	--	--	--	--

TABLE XXXIII

Average volume of stomach contents of P. waigiensis at Vedalai (August 1955-December 1957)

Year and month	No. of fish examined	Incidence of empty stomachs		Average points gained by each stomach (feeding intensity)
		No.	%	
1955				
August	2	--	--	2.5
September	5	--	--	14.0
October	6	1	16.7	9.0
November	12	8	66.7	7.0
December	27	10	37.0	9.9
1956				
January to March		No data		
April	37	10	27.0	14.6
May	33	9	27.3	7.6
June to December		No data		
1957				
January	23	10	43.5	7.0
February	11	2	18.2	10.7
March	18	1	5.6	9.8
April	1	--	--	15.0
May	45	9	20.0	7.6
June to November		No data		
December	1	1	100.0	--
Total	221	61	27.6	Grand average 19.6

February, March and April 1957 are found to be above the grand average, indicating intense feeding during these months. The incidence of empty stomachs during months of their occurrence, was highest in November 1955 (excluding December 1957 when only one fish was examined which had an empty stomach) and lowest in March 1957.

At Munakkad (Table XXXIV), the average feeding intensity during the period July 1955-September 1957 has been found to be 10.7. Feeding intensity values during August 1955 and July and September 1957 are found to be above the grand average, suggesting increased feeding during these months. The incidence of empty stomachs during months of their occurrence, was highest in July 1955 (excluding December 1956 when only one fish was examined which had an empty stomach) and lowest in September 1957.

At Devipatnam (Table XXXV), the average feeding intensity during the period September 1955-May 1956 has been found to be 9.9. Based on this, feeding intensity during September, October and December 1955 and March, April and May 1956 is found to be above the grand average, indicating high feeding activity during these months. The incidence of empty stomachs during months of their occurrence, was highest in January 1956 and lowest in October 1955.

At Tondi (Table XXXVI), the average feeding intensity during the period has been found out to

TABLE XXXIV

Average volume of stomach contents P. waigiensis at Munakkad (July 1955-September 1957)

Year and month	No. of fish examined	Incidence of empty stomachs		Average points gained by each stomach (feeding intensity)
		No.	%	
1955				
July	33	20	60.6	6.4
August	12	5	41.7	15.3
September to December		No data		
1956				
January to October		No data		
November	53	4	7.5	8.9
December	1	1	100.0	--
1957				
January to June		No data		
July	44	2	4.5	11.9
August	14	1	7.1	7.9
September	27	1	3.7	13.7
Total	184	34	18.5 Grand average	10.7

TABLE XXXV

Average volume of stomach contents of P. waigiensis at Devipatnam (September 1955-May 1956)

Year and month	No. of fish examined	Incidence of empty stomachs		Average points gained by each stomachs (feeding intensity)
		No.	%	
1955				
September	45	3	6.7	10.9
October	55	3	5.5	10.3
November	51	8	15.7	9.7
December	50	6	12.0	11.8
1956				
January	35	18	51.4	5.6
February	89	29	32.6	9.4
March	45	9	20.0	10.7
April	4	--	--	11.2
May	7	--	--	10.0
Total	381	76	19.9 Grand average	9.9

TABLE XXXVI

Average volume of stomach contents of P. waigiensis at Tondi (September 1955 - June 1956)

Year and month	No. of fish examined	Incidence of empty stomachs		Average points gained by each stomach (feeding intensity)
		No.	%	
1955				
September	11	--	--	12.3
October	37	2	5.4	12.3
November	46	1	2.2	9.4
December	No data			
1956				
January	50	4	8.0	8.7
February	50	5	10.0	10.5
March	39	4	10.3	8.3
April to May	No data			
June	50	8	16.0	5.9
Total	283	24	8.5 Grand average	9.6

be 9.6. Feeding intensity values during September and October 1956 and February 1956 are found to be above the grand average, suggesting increased feeding during these months. The incidence of empty stomachs during months of their occurrence was highest in June 1956 and lowest in November 1955.

iv. Food in relation to size

For the purpose of study of the food of fish in relation to size, fish are grouped as measuring below 15 cm. and above 15 cm. in total length. The data thus analysed with respect to different food components for the four centres are presented in Table XXXVII. From the table, it is clear that the greater incidence of prawns in the food of the fish in the Palk Bay is manifest in all fish. The greater incidence of crabs in the food of the fish in the Gulf of Mannar is manifest in fish above 15 cm. only; fish below 15 cm. feed relatively more on prawns. Fish above 15 cm. relatively consume more teleostean fishes and sea grass and algae in both the habitats, than those below 15 cm. The preference for other items of food is difficult to judge due to inadequacy of data.

v. Correlation between the stomach contents and their occurrence in the environment

The stomach contents of the fish at the four centres are presented in Table XXXVIII along with the

TABLE XXXVII

Food in relation to size of P. waigiensis at various centres
(1955 - 1957)

Centre	Total no.of fish examined	Fish below 15 cm. / Fish above 15 cm.	Percentage composition of food components									
			Crabs	Prawns	Teleostean fishes	Isopods	Stomotopods	Amphipods	Molluscs	Polychaetes	Sea grass and algae	Sand and mud
Vedalai	221	52	44.3	48.2	1.3	0.7	--	--	0.6	--	4.9	--
		169	63.0	18.3	9.9	1.0	--	--	1.6	--	6.1	0.1
Munakkad	184	100	8.5	67.3	1.4	19.2	--	1.8	1.0	--	0.8	--
		84	20.9	54.3	11.2	8.4	--	0.8	1.7	--	2.7	--
Devipatnam	381	95	0.9	85.5	9.5	3.3	--	--	--	--	0.8	--
		286	24.4	52.7	10.6	8.8	1.7	--	0.3	0.2	1.2	0.1
Tondi	283	90	3.9	90.2	1.3	3.8	--	--	0.8	--	--	--
		193	7.3	86.1	3.2	2.5	0.6	--	--	--	0.2	0.1

TABLE XXXVIII

Correlation between the stomach contents of P. waigiensis and their occurrence in the environment

Centre	Stomach contents		Environment	
	Flora	Fauna	Flora	Fauna
Vedalai	Angiosperms Cymodocea spp., Halophila ovalis Red algae Hypnea musciformis, Spyridia spp. Brown alga Sargassum tenerrimum	Brachyuran crabs Portunus pelagicus, Thalamita spp., Charybdis sp., Philyra globosa, Tylocarcinus styx Macrura Penaeus spp., Metapenaeus spp., Hippolysmata sp. Teleostean fishes Lethrinus spp., Lutjanus spp., Gerres spp., Caranx spp., Leiognathus spp., Epinephelus spp. Cynoglossus spp. Isopods Cymodoce spp. Molluscs Oliva spp., Littorina spp., Cerithium spp., Nerita spp.	Angiosperms Cymodocea rotundata, C. serrulata, Halophila ovalis Red algae Hypnea musciformis, Spyridia filamentosa Brown algae Sargassum tenerrimum Green alga Caulerpa racemosa	Brachyuran crabs Portunus pelagicus, Thalamita crenata, Charybdis annulata, Philyra globosa, Tylocarcinus styx, Menippe rumphii Macrura Penaeus monodon, Metapenaeus monoceros, Hippolysmata sp. Teleostean fishes Lethrinus cinereus, Gobiodon spp., Lutjanus spp., Therapon spp., Caranx spp., Allanetta forskåli Isopods Cymodoce spp. Stomatopods Squilla spp. Amphipods Amphipods Molluscs Oliva gibbosa, Nerita spp., Natica spp., Cerithium spp., Littorina spp.
Munakkad	Angiosperms Cymodocea spp., Halophila ovalis Red algae Hypnea musciformis, Spyridia spp. Brown alga Sargassum tenerrimum Green algae Caulerpa racemosa, Neomeris annulata	Brachyuran crabs Portunus spp., Thalamita spp., Charybdis spp., Menippe sp., Schizophrys aspera Macrura Penaeus monodon, Metapenaeus spp., carids Teleostean fishes Gobiodon spp., Lutjanus spp., Siganus oramin, Lethrinus spp., Allanetta forskåli, Triacanthus spp. Isopods Isopods Stomatopods Squilla spp. Amphipods Amphipods Molluscs Oliva spp., Littorina spp., Cerithium spp., Natica spp.	Angiosperms Cymodocea rotundata, Halophila ovalis Red algae Hypnea musciformis, Spyridia filamentosa, S. insignis Brown alga Sargassum tenerrimum Green algae Caulerpa racemosa var. corynephora, Neomeris annulata	Brachyuran crabs Portunus pelagicus, Charybdis annulata, Philyra globosa, Schizophrys aspera, Menippe rumphii Macrura Penaeus monodon, Metapenaeus monoceros, carids belonging to Processidae and Alphaeidae Teleostean fishes Lethrinus spp., Gobiodon spp., Lutjanus spp., Gerres spp., Siganus oramin, Caranx spp., Isopods Cymodoce spp. Epinephelus spp. Stomatopods Squilla spp. Amphipods Amphipods Molluscs Oliva sp., Natica sp., Cerithium spp., Turritella spp., Littorina spp., pelecypods

Continued

TABLE XXXVIII (Continued)

Correlation between the stomach contents of P. waigiensis and their occurrence in the environment

Centre	Stomach contents		Environment	
	Flora	Fauna	Flora	Fauna
Devipatnam	Angiosperms Cymodocea spp., Halophila ovalis Red alga Spyridia spp. Brown alga Sargassum tenerrimum Green algae Caulerpa racemosa, Acetabularia caliculus	Brachyuran crabs Portunus pelagicus, Thalamita spp., Tylocarcinus sp., Menippe rumphii Macrura Penaeus spp., Metapenaeus spp., carids Teleostean fishes Lutjanus spp., Therapon spp., Siganus spp., Platycephalus spp., Gerres spp.,Allanetta forskåli Isopods Cymodoce spp. Stomatopods Squilla spp. Molluscs Oliva spp., Natica spp., Nerita spp., Turritella spp., Littorina spp. Polychaetes Polychaetes	Angiosperms Cymodocea rotundata, C. serrulata, Halophila ovalis Red algae Hypnea musciformis, Spyridia filamentosa, S. insignis Green algae Neomeris annulata, Acetabularia caliculus, Caulerpa racemosa var. corynephora	Brachyuran crabs Portunus pelagicus, Thalamita crenata, Tylocarcinus sp., Schizophrys aspera Menippe rumphii Macrura Penaeus monodon, P. indicus, Metapenaeus monoceros, carids belonging to Processidae and Alphaeidae Teleostean fishes Lethrinus spp., Lutjanus johnii, Lutjanus spp., Therapon spp., Gerres spp., Platycephalus spp., Siganus spp., Cynoglossus spp., Allanetta forskåli Isopods Cymodoce spp. Stomatopods Squilla spp. Amphipods Amphipods Molluscs Oliva spp., Natica spp., Nerita spp., Cerithium spp., Turritella spp., pelecypods, cephalopods - Sepia sp.
Tondi	Angiosperms Cymodocea spp. Red algae Gracilaria lichenoides, Acanthophora spicifera, Roschera glomerulata, Spyridia spp. Green alga Neomeris annulata	Brachyuran crabs Thalamita spp., Philyra sp., Charybdis sp., Schizophrys aspera, Menippe rumphii Macrura Penaeus spp., Metapenaeus spp., carids Teleostean fishes Lethrinus spp., Lutjanus spp., Therapon spp., Siganus spp., Gerres spp., Allanetta forskåli, Cynoglossus spp., Triacanthus spp., Gobiodon spp. Isopods Isopods Stomatopods Squilla spp. Molluscs Oliva spp., Nerita spp., Natica spp., Cerithium spp., Turritella spp., pelecypods, cephalopods - Sepia sp.	Angiosperms Cymodocea rotundata, C. serrulata, Halophila ovalis Red algae Gracilaria lichenoides, Acanthophora spicifera, Hypnea musciformis, Roschera glomerulata Green algae Caulerpa racemosa var. laetevirens, Neomeris annulata	Brachyuran crabs Thalamita crenata, Philyra sp., Tylocarcinus sp., Schizophrys aspera, Menippe rumphii Macrura Penaeus indicus, Metapenaeus monoceros, Hippolysmata sp. Teleostean fishes Lutjanus spp., Pelates quadrilineatus, Therapon spp., Gerres spp., Platycephalus spp., Allanetta forskåli Isopods Isopods Stomatopods Squilla spp. Amphipods Amphipods Molluscs Cerithium spp., Natica spp., Turritella spp., Littorina spp., pelecypods

items (flora and fauna) found in the dredge samples collected at these centres. As could be expected, the flora and fauna met with in the environment are invariably the food items taken by the fish. This observation suggests that there is not much of selective feeding on the part of the fish. The fish being an omnivore with certain browsing habits, abounds in the shallow coastal waters of the Gulf of Manner and the Palk Bay, owing to the fact that they have dense growth of sea grass and algae which harbour rich crustacean fauna and young ones of teleostean fishes, the prime food of the fish.

In this connection, it may be remarked that the allied species Lates calcarifer takes to cannibalism (Menon, 1948). However, no evidence of cannibalistic tendency was found in P. waigiensis, although L. calcarifer feeds on almost the same items of food (Mookerjee, Ganguly and Mazumdar, 1946 and Menon, 1948).

CHAPTER 5

LENGTH-WEIGHT RELATIONSHIP AND RELATIVE CONDITION FACTOR

Length-weight relationship

In most fishes, weight is found to be roughly proportional to the cube of the length, i.e., the relationship between weight (W) and length (L) can be expressed as:

$$W = KL^3$$

But when this equation is fitted to the observed data, the fit is not always very satisfactory. On the other hand, the fitting of the general equation, $W = KL^n$ (where n is an exponent and K is a constant, whose values are to be obtained from observed data) gives better results. The task of fitting the above equation is facilitated by taking logarithm of the original data, which may then be written as:

$$\text{Log } W = \text{Log } K + n \text{ Log } L$$

$$\text{i.e.,} \quad Y = K^1 + nX$$

This is a linear equation where X and Y represent the logarithmised data of length and weight respectively. The values of K^1 and n can be obtained by the method of least squares. For this purpose, the two normal equations are formed as:

$$K^1 N + n\Sigma X = \Sigma Y$$

$$K^1 \Sigma X + n \Sigma X^2 = \Sigma XY$$

where

N = number of observations,

ΣX = sum of transformed length data,

ΣX^2 = sum of squares of transformed length data,

ΣY = sum of transformed weight data and

ΣXY = sum of products of transformed length and weight data for each observation.

Since these are known from observations, the solution of the above two equations gives K^1 and n. Antilogrithm of K^1 gives K . Hence, the equation $W = KL^n$ is obtained.

The value of n, an exponent was found to be usually lying between 2.5 and 4 (Hile, 1936; Martin, 1949). For all ideal fish which maintain the same shape, the value of n is expected to be 3 (Allen, 1938). Le Cren (1951) has reviewed the methods adopted in determining length-weight relationship of fishes, with the exposition of the superiority of the equation of the general parabola $W = KL^n$ over that of the cubic parabola $W = KL^3$. The formula $W = KL^n$, also provides a means of converting logarithmic growth-rates calculated on lengths into growth-rates for weight.

Crozier (1913) studied the correlations of weight, length, etc., in the weak-fish, Cynoscion regalis and Clark (1928) studied the weight-length relationship of the California sardine, Sardina caerulea at San Pedro. Chase (1946) calculated fish condition factors from scale dimensions in the bluegill, Lepomis macrochirus. Kesteven (1947) discussed the importance of studies on the ponderal

index as employed in fisheries biology.

The practical application of this study lies in the fact that weights of fish can be calculated from known lengths or vice versa. The value of the so-called condition factor or ponderal index K, which is based on a calculation of the length-weight relationship, fluctuates periodically with the seasons falling to a minimum in certain seasons and rising to a maximum in certain other seasons. It was pointed out by Hart (1946) that the point of inflexion on the curve showing a diminution of K with increasing length is a good indication of the length at which sexual maturity is attained. On similar lines Sarojini (1957), Radhakrishnan (1957) and Pillay (1958) approximately determined the spawning activity of many commercially important species. This statistical method is, therefore, useful to determine the spawning season with considerable accuracy.

Prabhu (1954) studied the length-weight relationship of five species of fish from the Mandapam area and found that this relationship for P. waigiensis may be represented by the equation $W = 0.01611L^{2.9153}$. A comparison of sexes, however, has not been done.

The data collected on 525 females ranging in total length between 11.4 cm. and 37.0 cm. and 443 males ranging in total length between 10.3 cm. and 24.2 cm. have been utilised in the present study. In Table XXXIX are presented the relevant statistics on corrected sums of squares and products. Table XL presents the analysis of covariance for comparing the relation between the two sexes. The F test shows that sexes differ significantly for this

TABLE XXXIX

Regression data of length-weight relationship of males and females of P. waigiensis

Source of variation	D.F.	Corrected sum of squares and products			Regression coefficient b	Residual error $S^2_{y.x}$	D.F.
		x^2	xy	y^2			
Within males	442	1.9280	6.1255	19.8647	3.1771	0.4032	441
Within females	524	4.1425	13.6776	45.3366	3.3018	0.1763	523
Within sexes	966	6.0705	19.8031	65.2013	3.2622	0.5999	965

D.F. = Degrees of freedom

TABLE XL

Analysis of covariance

Source of variation	D.F.	Sum of squares	Mean square	Observed F	Significance
Deviation from individual within-sex regression	964	0.5795	0.0006		
Differences between regressions	1	0.0204	0.0204	34	**
Deviation from average within-sex regression	965	0.5999			

D.F. = Degrees of freedom

** Significant at 1% probability level

relationship. A pooled length-weight relation between the two sexes is, therefore, not attempted. Separate relations for the two sexes are given below:

Females: $W = 0.004872L^{3.3018}$

$\log W = -2.3123 + 3.3018 \log L$

Males: $W = 0.007013L^{3.1771}$

$\log W = -2.1541 + 3.1771 \log L$

The observed and calculated values of weight in the females and the males are shown in Figs. 25 and 26 and their respective log values are delineated in Figs.27 and 28. The importance of the study of the length-weight relationship of the two sexes separately at various lengths lies in the fact that the sudden increase in weight of the fish on the attainment of first maturity can be traced from the parabola. From Fig.25, it could be seen that in the females, the increase in weight is gradual till they reach a size of about 14-16 cm,, followed by rapid increase in weight above the 14-16 cm. size, indicating attainment of maturity at about this size.

In the case of the males (Fig. 26), the increase in weight is gradual till they reach a size of about 12-14 cm. followed by a rapid increase beyond this size, suggesting attainment of maturity at about this size.

Fig. 25. Length-weight curve of P. waigiensis (female).

Fig. 26. Length-weight curve of P. waigiensis (male).

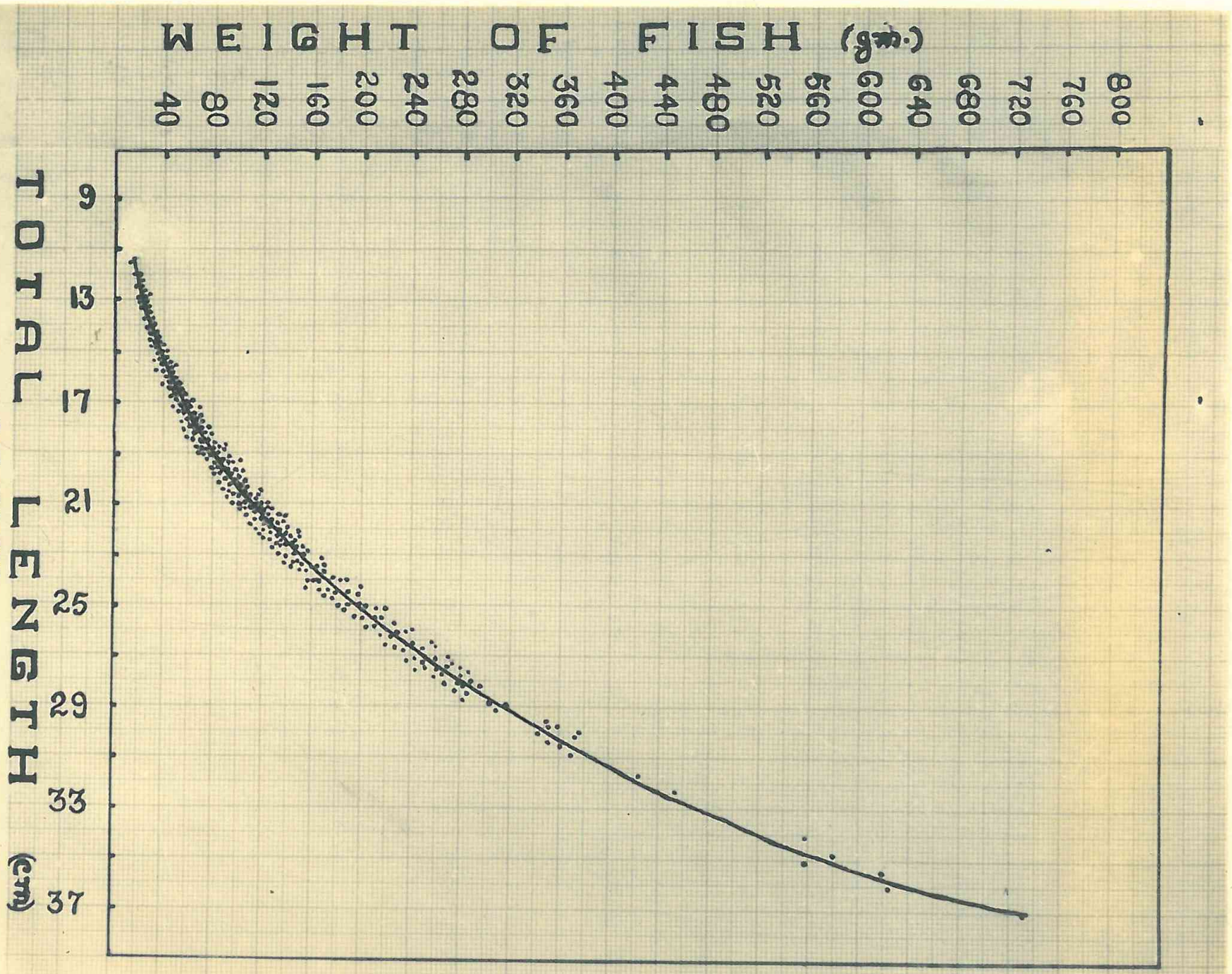

WEIGHT OF FISH (gm.)
40
80
120
160
200
240
280
320
360
400
440
480
520
560
600
640
680
720
760
800
TOTAL LENGTH OF FISH (cm)
9
13
17
21
25
29
33
37

Fig. 25

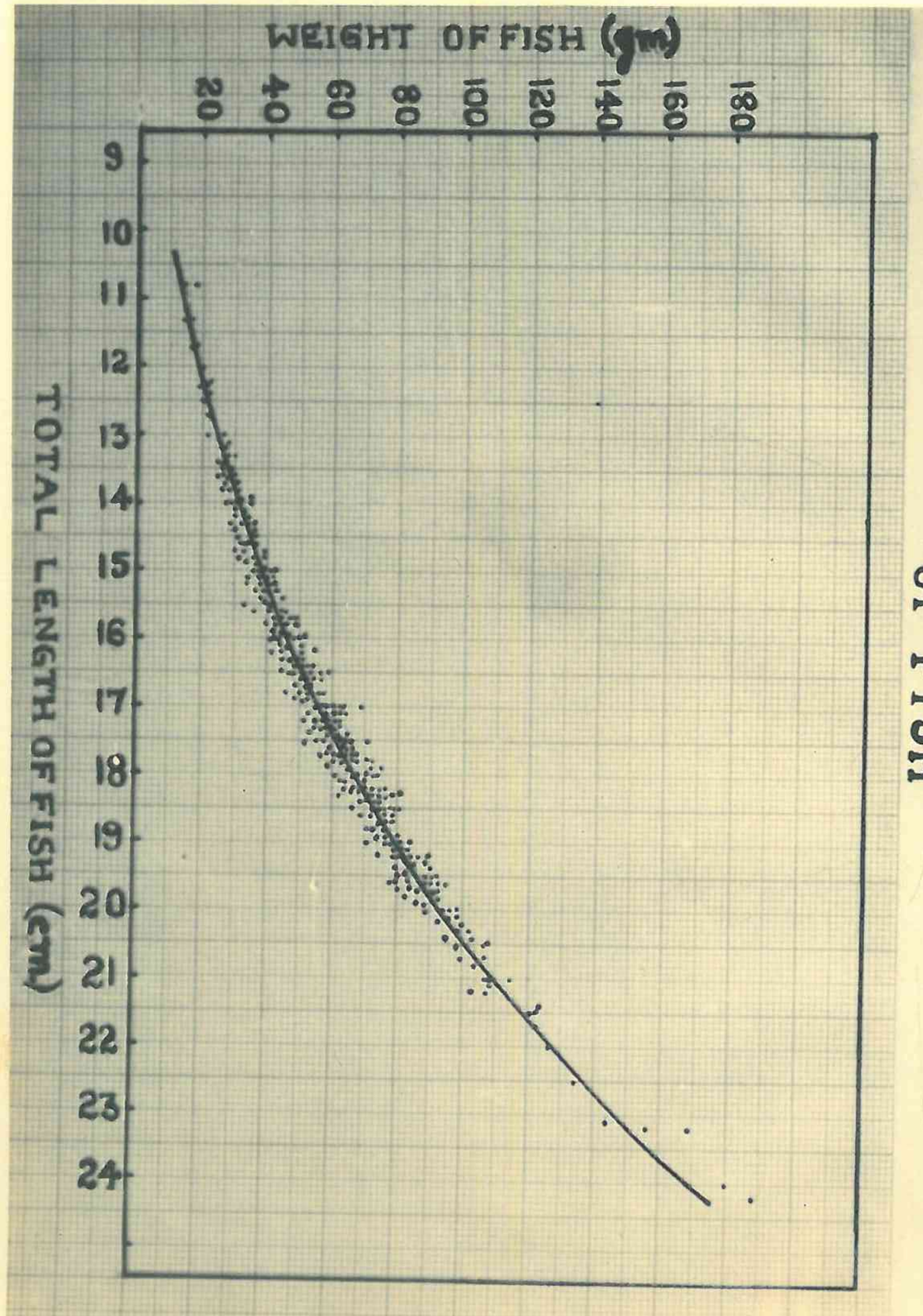

WEIGHT OF FISH (gm)
20
40
60
80
100
120
140
160
180
TOTAL LENGTH OF FISH (cm)
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24

Fig. 26

Fig. 27. Logarithmic relation of length and weight of *P. waigiensis* (female).

Fig. 28. Logarithmic relation of length and weight of *P. waigiensis* (male).

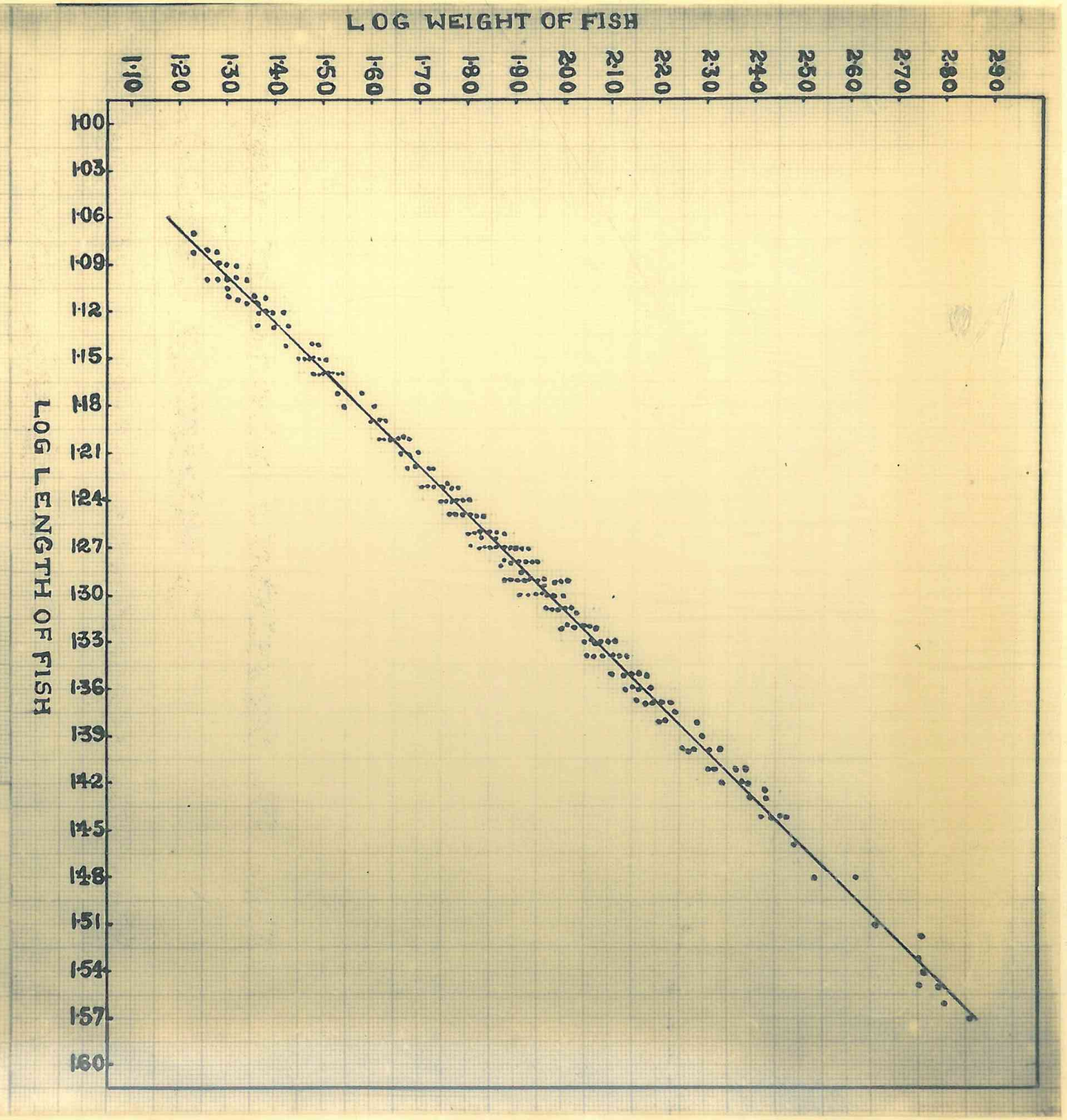

LOG WEIGHT OF FISH
1·10
1·20
1·30
1·40
1·50
1·60
1·70
1·80
1·90
2·00
2·10
2·20
2·30
2·40
2·50
2·60
2·70
2·80
2·90
1·00
1·03
1·06
1·09
1·12
1·15
1·18
1·21
1·24
1·27
1·30
1·33
1·36
1·39
1·42
1·45
1·48
1·51
1·54
1·57
1·60
LOG LENGTH OF FISH

Fig. 27

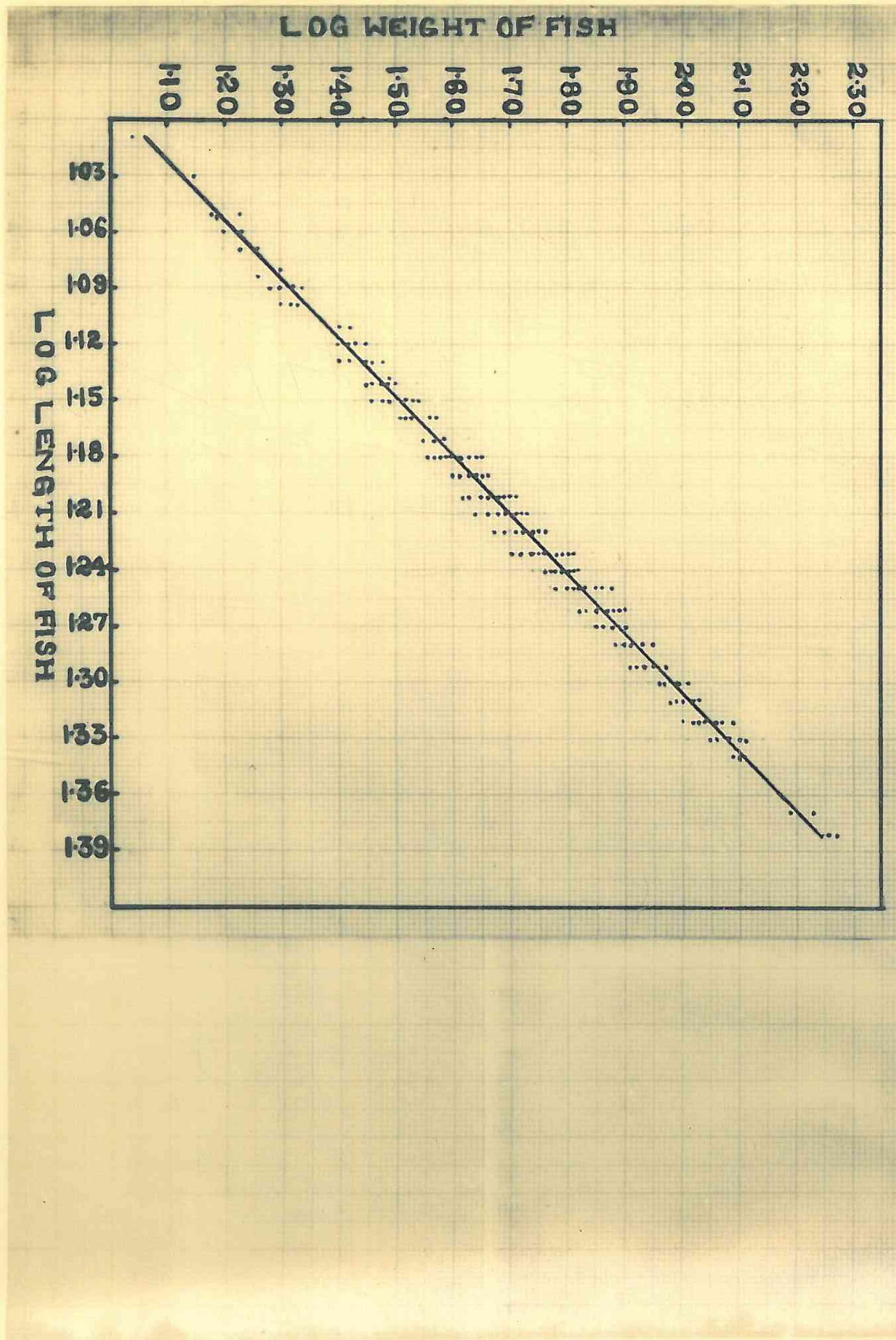

LOG WEIGHT OF FISH
1·10
1·20
1·30
1·40
1·50
1·60
1·70
1·80
1·90
2·00
2·10
2·20
2·30
1·03
1·06
1·09
1·12
1·15
1·18
1·21
1·24
1·27
1·30
1·33
1·36
1·39
LOG LENGTH OF FISH

Fig. 28

Relative condition factor

The condition factor or coefficient of condition values are interpreted as expressing the relative well-being of fishes. With a view to getting a numerical value for the condition of a fish, the simplest expression, W/L^n has often been used. For all ideal fishes which maintain the same shape, the value of n is expected to be 3 (Allen, 1938).

The calculation of the condition factor based on the empirical, calculated length-weight relationship $W = CL^n$ was suggested by Le Cren (1951) to eliminate the effect of length and other correlated factors on K and, this he termed the relative condition factor or K_n , to distinguish it from the condition factor K based on the cube law. The relative condition factor can be expressed as,

$$K_n = \frac{W}{\hat{W}}$$

where W is the observed weight of fish and $\hat{W}$ is the smoothed mean weight. Many workers have utilised the variation in the condition factor to determine the spawning season and size at first maturity of various species of fishes (Allen, 1938; Menon, 1950b; Davies, 1956; Sarojini, 1957 and Pillay, 1958). Allen (1938) in his studies on the trout, Salmo trutta found that the K values fluctuated with the seasons and correlated condition with the rate of growth. Menon (1950b) determined the spawning season and its duration in the poor-cod from studies on seasonal fluctuations of the ponderal index. Davies (1956) found that the condition factor was virtually the same

for male and female pilchards from the commercial catches, irrespective of the size of fish or the season. He also found that fluctuations in condition factor were not related to feeding or reproductive activities. Sarojini (1957) made similar studies on Mugil parsia. Pillay (1958) in his studies of Hilsa ilisha has found it possible to determine the spawning season and its extent from the seasonal fluctuations in the ponderal index.

Relative condition factor in relation to size

The relative condition factor for P. waigiensis was calculated for individual fish and the values obtained were grouped according to the size of fish for males and females separately (Table XLI). The mean K_n values were multiplied by 10^2 to obtain values of the order of 100. As could be seen from Table XLI, the K_n value fluctuates in the various size-groups of males and, hence, it has not been useful to determine the size at maturity. A similar trend has been observed in the case of females also.

Seasonal variation in relative condition factor

The seasonal variation of relative condition factor of adult females was studied in order to find its relation to spawning. The mean K_n values for the period June 1955 - December 1956 are given in Table XLII. The value of K_n fluctuates between the months, but taking the grand average (102.24) for the entire period, it may be seen that K_n values were above the grand average during October and November 1955 and April, September, October, November and

TABLE XLI

Mean relative condition factor at different sizes of males and females of P. waigiensis

Size-group (cm.)	Mean relative condition factor	
	Males	Females
10 - 11	101.75	--
11 - 12	100.44	105.80
12 - 13	99.35	99.29
13 - 14	101.34	100.78
14 - 15	99.26	99.49
15- 16	98.94	100.79
16 - 17	99.93	100.55
17 - 18	100.88	100.14
18 - 19	99.50	98.44
19 - 20	99.50	100.82
20 - 21	100.41	98.19
21 - 22	100.83	100.12
22 - 23	--	101.13
23 - 24	106.37	97.60
24 - 25	107.60	99.17
25 - 26	--	101.53
26 - 27	--	103.28
27 - 28	--	100.58
28 - 29	--	96.11
29 - 30	--	99.93
30 - 31	--	113.10
31 - 32	--	--
32 - 33	--	96.90
33 - 34	--	108.50
34 - 35	--	99.70
35 - 36	--	101.10
36 - 37	--	99.61

TABLE XLII

Mean relative condition factor of adult females of *P. waigiensis* during different months (June 1955 - December 1956)

Year and month	Mean relative condition factor
1955	
June	--
July	93.98
August	95.19
September	98.86
October	107.35
November	103.53
December	101.43
1956	
January	100.27
February	100.26
March	No data
April	109.45
May	--
June	--
July	96.38
August	99.74
September	107.05
October	106.88
November	105.63
December	107.57
Grand average	102.24

December 1956 and the rest below it. The data, therefore, suggest that the relative condition factor is high during peak spawning months.

CHAPTER 6

TOTAL LENGTH-STANDARD LENGTH RELATIONSHIP

An analysis of the relationship between the total length and the standard length of P. waigiensis was made with a view to determining the degree of association of these two characters and to establish an equation for the conversion of one measurement into the other.

The data collected from 123 females ranging in total length between 9.9 cm. and 37.0 cm. and 111 males ranging in total length between 10.8 cm. and 24.2 cm. have been used in this study. The relationship was calculated for the two sexes separately and these have been found to be:

$$\text{Males: } Y = -0.8637 + 0.9253\ X$$

$$\text{Females: } Y = -0.6570 + 0.9153\ X$$

where Y = standard length in centimetres and

X = total length in centimetres.

Comparisons between the regressions of standard length on total length of the two sexes were made by the method of analysis of covariance. In Table XLIII are given the relevant statistics on corrected sums of squares and products along with the values of regression coefficients and the sum of squares of deviations from the regressions. In Table XLIV are presented the relevant analysis of covariance. The mean square for the difference between the two regression lines is found to be less than the mean square of deviation

TABLE XLIII

Regression data of total length-standard length relationship of males and females of P. waigiensis

Source of variation	D.F.	Corrected sum of squares and products			Regression coefficient	Residual error	D.F.
		x^2	xy	y^2	b	$S^2_{y.x}$	
Within males	110	1058.17	979.09	913.76	0.9253	7.8401	109
Within females	122	2010.33	1840.15	1693.67	0.9153	9.2938	121
Within sexes	232	3068.50	2819.24	2607.43	0.9188	17.2022	231

D.F. = Degrees of freedom

TABLE XLIV

Analysis of covariance

Source of variation	D.F.	Sum of squares	Mean square	Observed F	Significance
Deviation from individual within-sex regression	230	17.1339	0.0745	1.0908	N.S.
Differences between regressions	1	0.0683	0.0683		
Deviation from average within-sex regression	231	17.2023			

D.F. = Degrees of freedom

N.S. = Non-significant

from individual within sex regressions. Obviously, the difference in regressions between the two sexes is non-significant.

As there is no significant difference in total length-standard length relationship for the two sexes, a common relation was obtained by pooling the data relating to males and females and it has been found to be:

$$Y = -0.7641 + 0.9202\ X$$

For easy reference, a conversion Table XLV is given between total length and standard length.

TABLE XLV

Conversion between total length and standard length of P. waigiensis

Total length (cm.) X	Standard length (cm.) Y
10.00	8.44
11.00	9.36
12.00	10.28
13.00	11.20
14.00	12.12
15.00	13.04
16.00	13.96
17.00	14.88
18.00	15.80
19.00	16.72
20.00	17.64
21.00	18.56
22.00	19.48
23.00	20.40
24.00	21.32
25.00	22.24
26.00	23.16
27.00	24.08
28.00	25.00
29.00	25.92
30.00	26.84
31.00	27.76
32.00	28.68
33.00	29.60
34.00	30.52
35.00	31.44
36.00	32.36
37.00	33.28

CHAPTER 7

MORPHOMETRIC STUDY AND RELATIVE GROWTH OF BODY PARTS

Morphometric study

It is well known that genetic difference induces small variations in morphometric and meristic characters, which though not easily perceptible by the examination of individual specimens, become obvious, by statistical comparison of large samples. Environmental conditions are also known to induce phenotypic differences in morphometric and meristic characters. Statistical comparisons may show these differences, but it is often difficult to determine whether the differences are due to genetic or environmental conditions.

The purpose of the present study is to determine whether fish drawn from the Gulf of Mannar and the Palk Bay are morphometrically comparable and whether any of the characters will be most useful in future racial studies of P. waigiensis.

The material for the study was collected in May 1964 and consisted of a sample of 108 fish from the Gulf of Mannar (Vedalai) and another sample of 95 fish from the Palk Bay (Munakkad). The size range of the fish in both samples was from 7.0 cm. to 27.0 cm. total length. Fifteen morphometric characters have been analysed in detail. Since the measurements could not be taken in the field, the samples were preserved entire in 5% formalin and brought to

the laboratory. In order to ensure uniformity of the material studied, measurements were taken one month after preservation.

The fifteen characters studied here are defined below:

Symbol	Character	Definition
X	Total length	Tip of the snout to the longest median caudal ray. The measurement is a straight line and is not taken over the curve of the body.
Y1	Snout	Tip of the upper jaw to the front margin of the orbit.
Y2	Head length	Tip of the snout to the farthest tip of opercular membrane.
Y3	Eye diameter	Maximum distance from the front margin to the hind margin of eye, along the long axis of body.
Y4	Post-orbital distance	Hind margin of orbit to the tip of opercular membrane.
Y5	Inter-orbital distance	Distance between the dorsal margins of orbits.
Y6	Snout to insertion first dorsal	Tip of the snout to the insertion of first dorsal fin.
Y7	Snout to insertion second dorsal	Tip of the snout to the insertion of second dorsal fin.
Y8	Snout to insertion pectoral	Tip of the snout to the insertion of pectoral fin.
Y9	Snout to insertion pelvic	Tip of the snout to the insertion of pelvic fin.
Y10	Snout to insertion anal	Tip of the snout to the insertion of anal fin.
Y11	First dorsal to anal	Insertion of first dorsal fin to the insertion of anal fin.

Symbol	Character	Definition
Y12	Second dorsal to anal	Insertion of second dorsal fin to the insertion of anal fin.
Y13	Depth of head	From the dorsal margin of head to the ventral margin through orbit.
Y14	Depth of caudal peduncle	Least depth of that part.
Y15	Back depth	Insertion of pectoral fin to the insertion of first dorsal fin.

Comparison of the samples has been made by the standard method of analysis of covariance (Snedecor, 1961) by comparing the regressions of a particular character (Yi) on the total length (X). Before applying the method of covariance analysis, scatter diagrams (Fig. 29) of measurements of different characters on total length were examined and in each case, the relation has been found to be linear. The relation is of the type,

$$Y = a + b X$$

where Y is one character, X is total length of fish and a and b are parameters to be estimated from the data.

The relevant statistics of regression analyses of the body measurements of P. waigiensis from the Gulf of Mannar and the Palk Bay are given in Table XLVI and the analysis of covariance for comparing the regressions of each of the fifteen morphometric characters from the two

Fig. 29. Relation between length and 15 morphometric characters (measured in centimetres) of P. waigiensis.

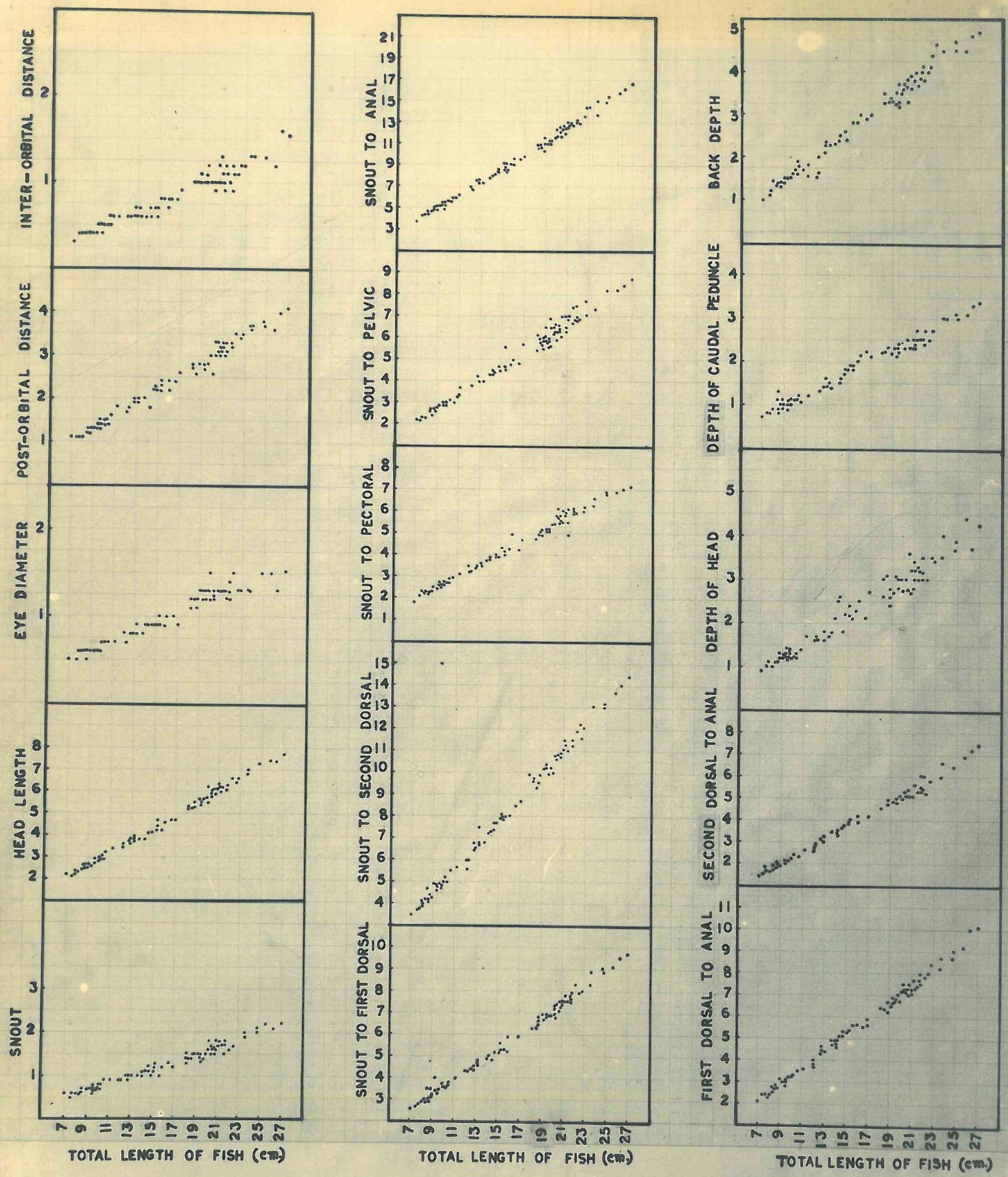

INTER-ORBITAL DISTANCE
POST-ORBITAL DISTANCE
EYE DIAMETER
HEAD LENGTH
SNOUT
SNOUT TO ANAL
SNOUT TO PELVIC
SNOUT TO PECTORAL
SNOUT TO SECOND DORSAL
SNOUT TO FIRST DORSAL
BACK DEPTH
DEPTH OF CAUDAL PEDUNCLE
DEPTH OF HEAD
SECOND DORSAL TO ANAL
FIRST DORSAL TO ANAL
TOTAL LENGTH OF FISH (cm.)

Fig. 29

TABLE XLVI

Statistics of regression analyses of the body measurements of P. waigiensis from the Gulf of Mannar and Palk Bay

Character	Gulf of Mannar			Palk Bay			Average		
	Regression coefficient b	Residual sum of squares $s^2_{y.x}$	D.F.	Regression coefficient b	Residual sum of squares $s^2_{y.x}$	D.F.	Regression coefficient b	Residual sum of squares $s^2_{y.x}$	D.F.
Snout	0.0714	0.6985	106	0.0813	0.5434	93	0.0765	1.3843	200
Head length	0.2754	3.3374	106	0.2891	1.5366	93	0.2824	5.1490	200
Eye diameter	0.0523	0.4133	106	0.0549	0.3777	93	0.0536	0.8010	200
Post-orbital distance	0.1512	0.4182	106	0.1529	0.9248	93	0.1521	1.3475	200
Inter-orbital distance	0.0536	0.6579	106	0.0542	0.5313	93	0.0539	1.1897	200
Snout to insertion first dorsal	0.3457	3.0985	106	0.3525	2.5610	93	0.3492	5.7273	200
Snout to insertion second dorsal	0.5434	8.6608	106	0.5437	2.5954	93	0.5435	11.2570	200
Snout to insertion pectoral	0.2704	2.7869	106	0.2711	2.1243	93	0.2708	4.9122	200
Snout to insertion pelvic	0.3344	6.0402	106	0.3217	3.1813	93	0.3279	9.4577	200
Snout to insertion anal	0.6286	5.4764	106	0.6292	4.9377	93	0.6289	10.4150	200
First dorsal to anal	0.3800	2.4797	106	0.3828	2.6069	93	0.3814	5.0981	200
Second dorsal to anal	0.2774	2.2810	106	0.2830	1.9443	93	0.2803	4.2701	200
Depth of head	0.1560	2.3344	106	0.1597	5.4113	93	0.1579	7.7760	200
Depth of caudal peduncle	0.1273	0.8834	106	0.1277	0.7686	93	0.1275	1.6521	200
Back depth	0.1855	8.7380	106	0.1998	1.1963	93	0.1928	10.2338	200

D.F. = Degrees of freedom

TABLE XLVII

Test of heterogeneity of regressions within samples of P. waigiensis from the Gulf of Mannar and Palk Bay

Character	Deviations from average total regressions within places		Deviations from individual regressions within places			Differences between regressions			Observed F	Significance
	D.F.	Sum of squares	D.F.	Sum of squares	Mean square	D.F.	Sum of squares	Mean square		
Snout	200	1.3843	199	1.2419	0.0062	1	0.1424	0.1424	22.9677	**
Head length	200	5.1490	199	4.8740	0.0245	1	0.2750	0.2750	11.2245	**
Eye diameter	200	0.8010	199	0.7910	0.0040	1	0.0100	0.0100	2.5000	N.S.
Post-orbital distance	200	1.3475	199	1.3430	0.0067	1	0.0045	0.0045	--	--
Inter-orbital distance	200	1.1897	199	1.1891	0.0060	1	0.0006	0.0006	--	--
Snout to insertion first dorsal	200	5.7273	199	5.6595	0.0284	1	0.0678	0.0678	2.3873	N.S.
Snout to insertion second dorsal	200	11.2570	199	11.2562	0.0566	1	0.0008	0.0008	--	--
Snout to insertion pectoral	200	4.9122	199	4.9112	0.0247	1	0.0010	0.0010	--	--
Snout to insertion pelvic	200	9.4577	199	9.2215	0.0463	1	0.2362	0.2362	5.1015	*
Snout to insertion anal	200	10.4150	199	10.4141	0.0523	1	0.0009	0.0009	--	--
First dorsal to anal	200	5.0981	199	5.0866	0.0256	1	0.0115	0.0115	--	--
Second dorsal to anal	200	4.2701	199	4.2253	0.0212	1	0.0448	0.0448	2.1132	N.S.
Depth of head	200	7.7760	199	7.7457	0.0389	1	0.0303	0.0303	--	--
Depth of caudal peduncle	200	1.6521	199	1.6520	0.0083	1	0.0001	0.0001	--	--
Back depth	200	10.2338	199	9.9343	0.0499	1	0.2995	0.2995	6.0020	*

D.F. = Degrees of freedom

5%F = 3.89; 1%F = 6.76

** Significant at 1% probability level

* Significant at 5% probability level

N.S. Non-significant

— Mean square less than that against which it is tested

samples in Table XLVII. It may be seen that out of the fifteen characters studied, eleven characters showed no significant differences. The regressions of the two characters, viz., snout to insertion pelvic (Y9) and back depth (Y15) showed significant differences at 5% level of significance but not at 1% level. The regressions of snout (Y1) and head length (Y2) showed, however, significant differences even at 1% level.

This preliminary morphometric study of P. waigiensis from the Gulf of Mannar and the Palk Bay, therefore, suggests that the four characters, viz., snout, head length, snout to insertion pelvic and back depth which have shown significant differences at 1% and 5% level, might be useful in further intensive studies on raciation of the species; but the possibility of such differences being intra-sample variations has not been completely ruled out.

Relative growth of body parts

With a view to studying the relative growth rates of body parts of P. waigiensis, data collected from 95 fish ranging in total length from 7.0 cm. to 27.0 cm. during May 1964 at Munakkad (Palk Bay) have been analysed. Measurements of formalin preserved specimens were taken. The measurements include the fifteen defined in 'Morphometric study' and six others defined in the next page.

Character	Definition
Depth of body at first dorsal	Depth of body at the insertion of first dorsal fin.
Maximum depth of body	Depth of body in line with the tip of pelvic fin.
Depth of body at vent	Depth of body in line with the vent.
Breadth of body at first dorsal	Breadth in the upper half of body in line with the insertion of first dorsal fin.
Breadth of body at maximum depth	Breadth in the upper half of body in line with the tip of pelvic fin.
Breadth of body above vent	Breadth in the upper half of body above the vent.

All the twenty one characters have been compared with the total length of fish.

Scatter diagrams of the comparison of characters with the total length of fish, as shown in Figs. 29 and 30, indicate that the relation is linear in all cases. The relation is of the type,

$$Y = a + b X$$

where Y is one character, X is total length of fish and a and b are parameters to be estimated from the data. Least square estimates of a and b are given in Table XLVIII for each of the characters, arranged according to the descending order of magnitude of b.

Fig. 30. Relation between length and 6 morphometric characters (measured in centimetres) of P. waigiensis.

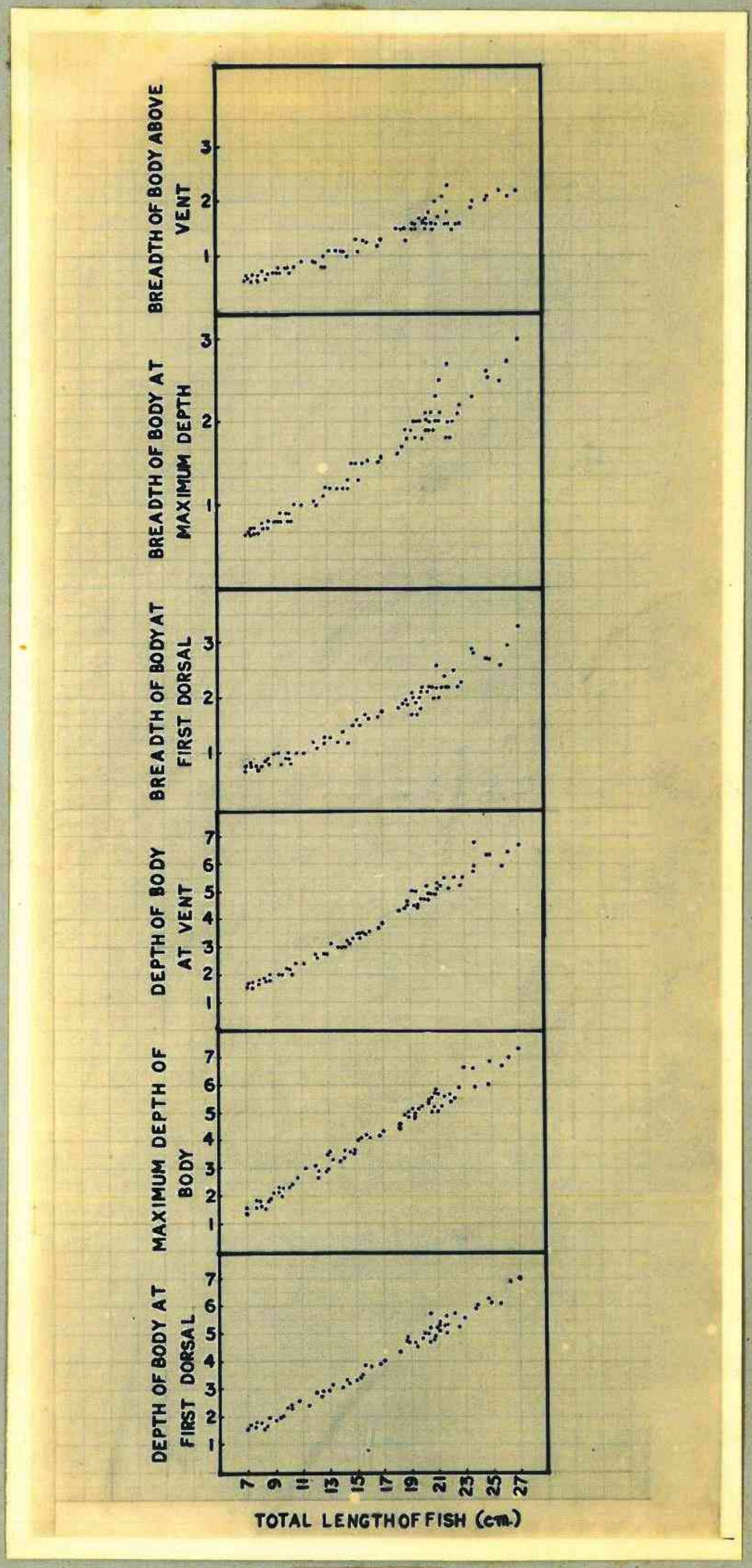

DEPTH OF BODY AT FIRST DORSAL
BREADTH OF BODY AT FIRST DORSAL
MAXIMUM DEPTH OF BODY
BREADTH OF BODY AT MAXIMUM DEPTH
DEPTH OF BODY AT VENT
BREADTH OF BODY ABOVE VENT
TOTAL LENGTH OF FISH (cm.)

Fig. 30

TABLE XLVIII

Least square estimates of a and b for each of the body measurements of P. waigiensis according to the descending order of magnitude of b.

S.No.	Character	a	b
1.	Snout to insertion anal	-0.7506	0.6292
2.	Snout to insertion second dorsal	-0.4071	0.5437
3.	First dorsal to anal	-0.6090	0.3828
4.	Snout to insertion first dorsal	0.0202	0.3525
5.	Snout to insertion pelvic	-0.1684	0.3217
6.	Maximum depth of body	-0.8991	0.2995
7.	Head length	-0.0143	0.2891
8.	Second dorsal to anal	-0.5862	0.2830
9.	Depth of body at first dorsal	-0.7623	0.2807
10.	Depth of body at vent	-0.7397	0.2743
11.	Snout to insertion pectoral	0.0119	0.2711
12.	Back depth	-0.3664	0.1998
13.	Depth of head	-0.2359	0.1597
14.	Post-orbital distance	-0.0732	0.1529
15.	Depth of caudal peduncle	-0.1908	0.1277
16.	Breadth of body at first dorsal	-0.3100	0.1216
17.	Breadth of body at maximum depth	-0.2017	0.1067
18.	Breadth of body above vent	-0.1606	0.0885
19.	Snout	-0.0607	0.0813
20.	Eye diameter	0.1196	0.0549
21.	Inter-orbital distance	-0.0510	0.0542

Of the twenty one characters studied, the rates of growth of eye diameter and that of interorbital distance in relation to total length appear to be comparatively less than all the other characters. While there may be slight differences amongst the other characters, the trend seems to be generally similar. The fastest rate of growth in relation to total length is exhibited by the character, snout to anal fin followed by that of snout to second dorsal fin and first dorsal to anal fin.

CHAPTER 8

FISHING SEASONS, GEAR AND CATCH DATA

Fishing seasons and places of fishery importance

Even though P. waigiensis supports a fishery in the Palk Bay and Gulf of Mannar in the vicinity of Mandapam, the magnitude of the fishery has not been recorded in any of the earlier reports. The existence of this fishery has been recorded as early as in 1932 (Raj, 1932). Prabhu (1954) recorded this species from the trap catches around Mandapam, but did not indicate the magnitude of the fishery in the area. According to him, the estimated annual yield comprising 23 species from perch trapping in the Palk Bay and Gulf of Mannar during the year 1951 was 47,280 kg.

Fishing is carried out in the Palk Bay during May to August, due to turbulence in the Gulf of Mannar caused by South West monsoon. In the Gulf of Mannar, fishing is carried out during September to April, owing to rough conditions in the Palk Bay caused by North East monsoon. Therefore, during the major part of the year lasting eight months, the fishing operations are at their highest in the Gulf of Mannar, whereas the operations in the Palk Bay last only four months. While the restricted seasons are applicable to Vedalai and Munakkad, fishing at Devipatnam and Tondi is carried out all round the year which is facilitated by the difference in the type of gear used.

The catches of P. waigiensis at various

fishing hamlets between Tondi (Lat. 9° 45' 09"N; Long. 79° 01' 09"E) in the Palk Bay and Tuticorin (Lat. 8° 48' 12"N; Long. 78° 90' 45"E) in the Gulf of Mannar have been examined. The location of the places where a good fishery exists is given below:

S.No.	Fishing hamlet	Position	
		Latitude	Longitude
1	Tondi*	9° 45' 09" N	79° 01' 09" E
2	Soliacoory	9° 42' 45" N	78° 59' 30" E
3	Tirupalakudi	9° 32' 45" N	78° 54' 36" E
4	Devipatnam*	9° 28' 51" N	78° 54' 00" E
5	Mudiapatnam	9° 25' 42" N	78° 54' 54" E
6	Munakkad*	9° 17' 30" N	79° 08' 00" E
7	Rameswaram	9° 17' 42" N	79° 19' 30" E
8	Vedalai*	9° 15' 45" N	79° 06' 15" E
9	Kilakarai	9° 14' 09" N	78° 46' 44" E

* Collection centres

Apart from the four collection centres (Tondi, Devipatnam, Munakkad and Vedalai), good catches of P. waigiensis are recorded at Soliacoory, Tirupalakudi, Mudiapatnam and Rameswaram in the Palk Bay and Kilakarai in the Gulf of Mannar.

At Soliacoory, hooks & lines mainly account for the catches. Further south at Tirupalakudi, this species

yields an exceptionally good fishery which is due to three types of gear, viz., hooks & lines and two types of shore seine called locally 'Olai Valai' ('Olai'= palmyrah leaf; 'Valai' = net) and 'Karai Valai' ('Karai'= shore; 'Valai' = net). The former type of shore seine is differentiated from the latter by the presence of dried palmyrah leaves in the head rope which subserves the function of a scare line and also by its smaller size. It was learnt from local reports that the fishery at Tirupalakudi is perennial and is of the same magnitude as that at Devipatnam. At Mudiapatnam, two types of gear, viz., hooks & lines and the shore seine ('Olai Valai') account for the catches. Occasionally, good catches of this species have been reported from Rameswaram where one-entrance traps are mainly operated for this species. At Kilakarai, this species is mainly caught by one-entrance traps. Occasionally, 'Olai Valai' also brings in good catches of P. waigiensis. Further south at Tuticorin, only stray specimens have been recorded.

Gear

The landings of this species are mainly from four types of gear, viz., traps ('Koodu'), shore seines ('Olai Valai' and 'Karai Valai'), bottom-set gill nets ('Kannikka Valai' or 'Senganni Valai') and hooks & lines ('Thoondi'). At Vedalai and Munakkad, one-entrance traps are the commonest gear employed; occasionally, the shore seine 'Olai Valai' is also used. At Devipatnam, hooks &

lines account for the major part of the landings followed by gill nets and shore seines ('Olai Valai' and 'Karai Valai'). At Tondi, the shore seine 'Olai Valai' is used frequently and gill nets occasionally.

1. Traps ('Koodu')

The perch traps and their construction and operation by the Rameswaram fishermen have been described by Hornell (1950).

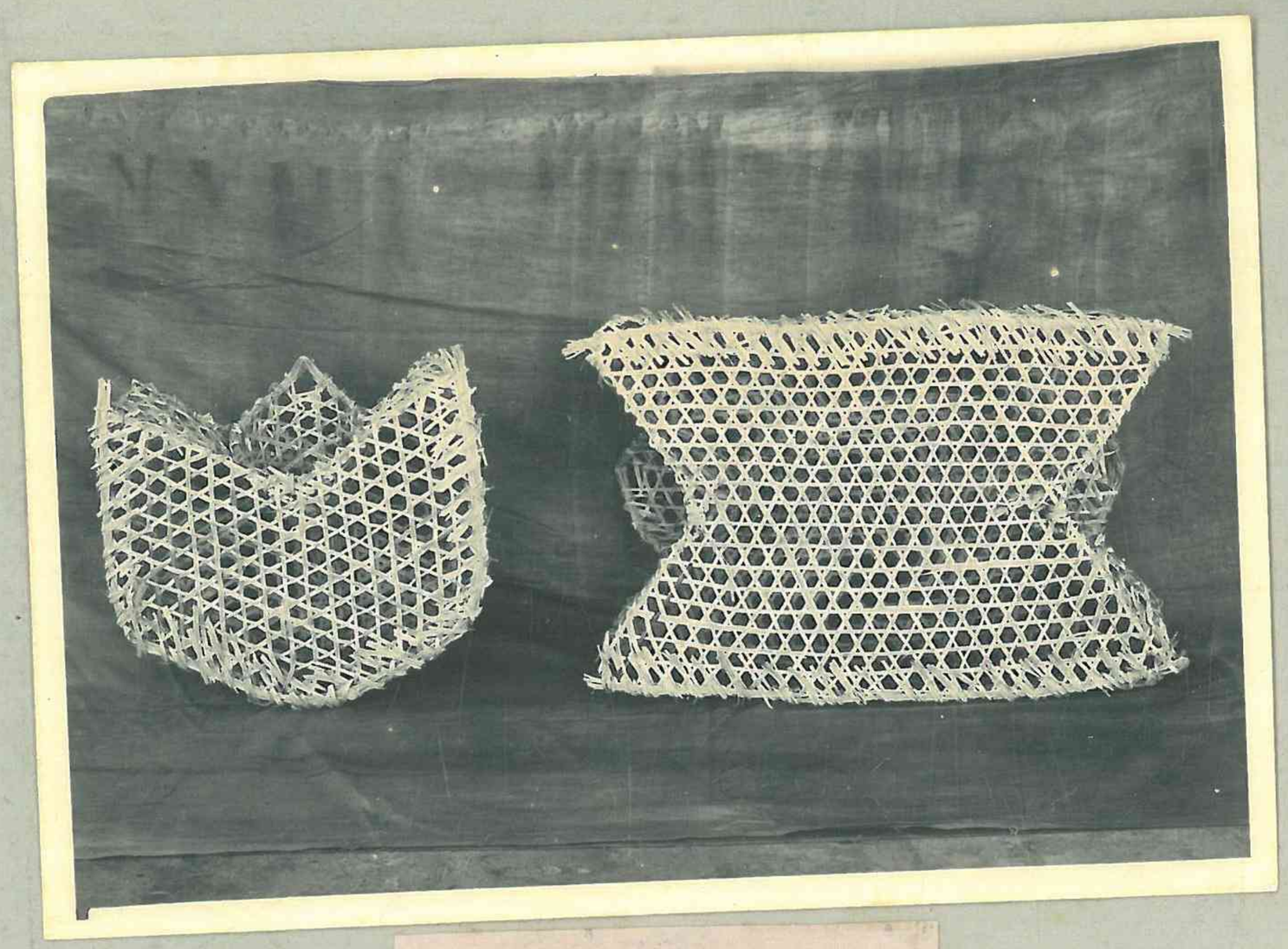
Traps (Photographs 12 to 14) with one to five entrances are used in the perch fishery along the coasts of Palk Bay and Gulf of Mannar, but one-entrance traps are most commonly used. Traps are either made out of split branches of Acacia planifrons which grows extensively in the Ramnad District or out of thin bamboo reepers and midribs of palmyrah leaves. Traps woven out of split withies of Acacia are, however, more durable. Before weaving the traps, the material is soaked in water for some time to make it more pliable.

The simplest form of trap has a single entrance and is roughly heart-shaped with angular corners. At the centre of one of the sides (Photograph 12), a wide aperture leads into a funnel; this turns sharply downwards at its inner end without any armature of spikes. In the more complicated 2-5 entrance traps, the entrance is provided in the angle formed between any two arms. The mesh work in all these types is hexagonal and the mode of construction

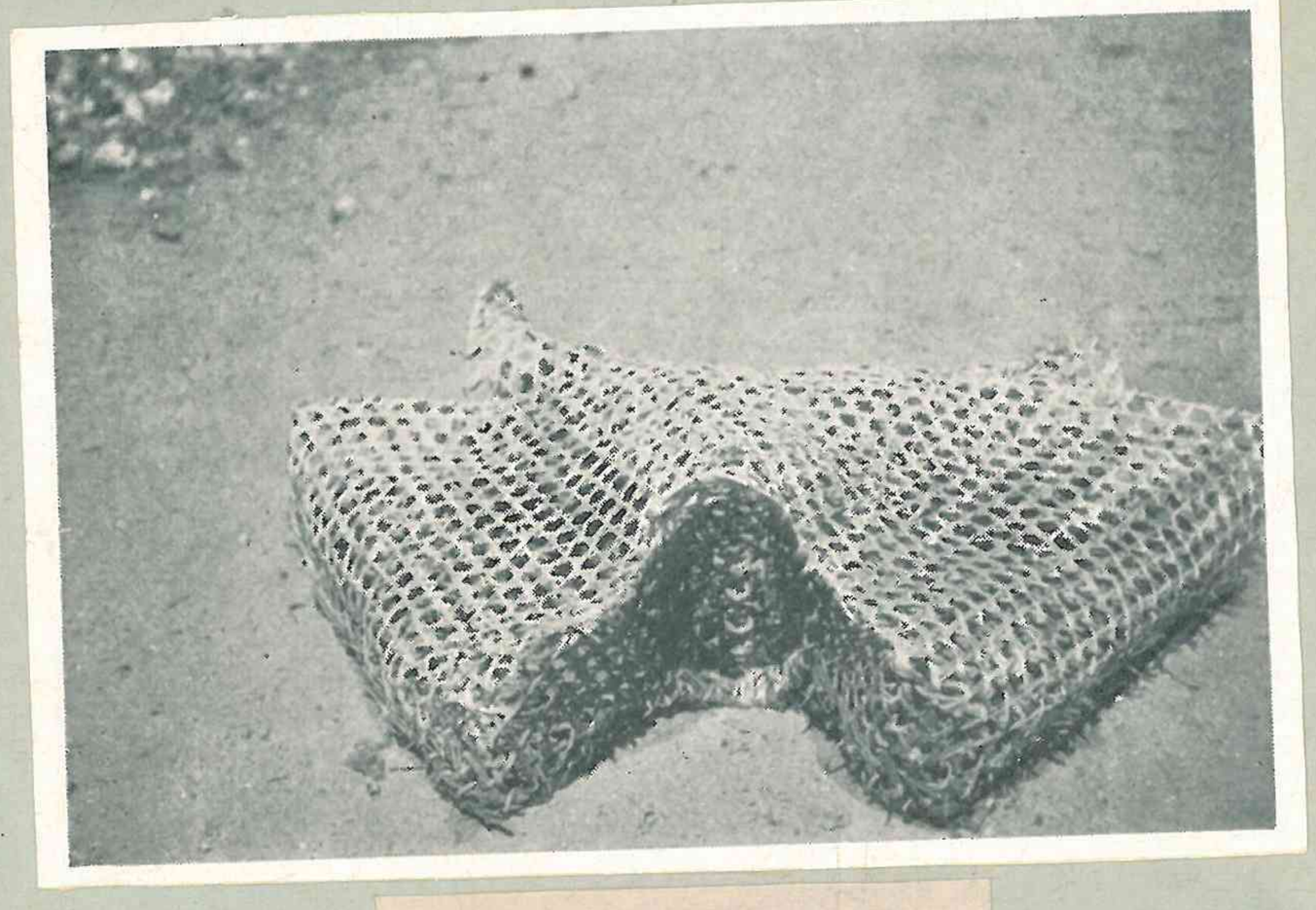
Photograph 12. Left - Trap with one entrance.
Right- Trap with two entrances.

Photograph 13. Trap with three entrances.

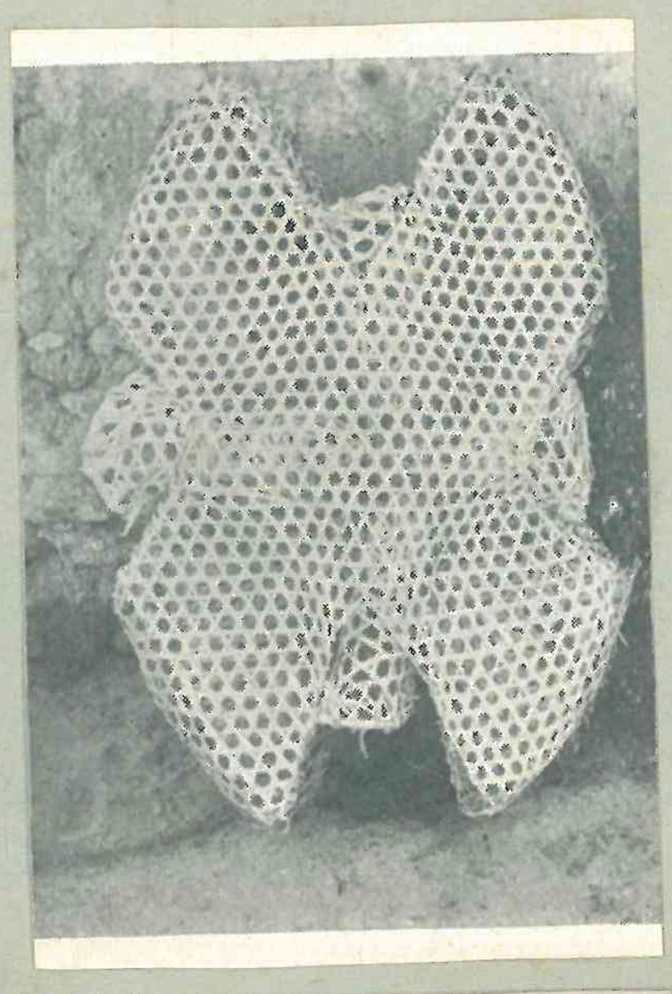
Photograph 14. Trap with four entrances.



Photograph 12



Photograph 13



Photograph 14

is exceedingly ingenious. The pattern evolved is such that the whole trap excepting funnels is made from two sheets of basket work; one, the bottom is so shaped as to form the final outline which the trap will have; the other is more intricate, as it provides not only the upper surface of the trap but also the sides by means of flaps and extensions. The lower edges of the sides are laced to the edges of the bottom and the trap is completed by inserting the entrance funnels into position.

The dimensions of one-entrance and two-entrance traps which are used in the fishery for percoids are detailed below:

Type of trap	Length of the trap (cm.)	Width of the trap at bottom (cm.)	Width of the trap above sides (cm.)	Length of the entrance funnel (cm.)	Width of the entrance funnel (cm.)	Height of the entrance funnel (cm.)	Mesh side (cm.)
One-entrance trap	From entrance to back end 37.5	42.5	67.5	27.5	15.0	22.5	1.9 (Hexagonal)
Two-entrance trap	From entrance to entrance 62.5	43.8	71.3	27.5	15.0	25.0	1.9

Operation of traps on sandy bottom

Smaller one-entrance traps are operated on

sandy bottom primarily for Psammoperca waigiensis, Lethrinus spp., Lutjanus spp., Therapon spp., Epinephelus spp., Plectorhynchus spp. and Gerres spp.

About 50 to 60 traps with single openings are tied to a coir rope at an interval of 3-5 metres with bait and stones inside; stones serve the purpose of sinking the traps to the bottom to make them stationary. At either end of the series, a float (usually coconut husk) is attached to help detection of the traps on the next day. The traps are transported to the fishing spot in a catamaran or a canoe by two fishermen and allowed to sink to the bottom at depths varying between 2-3 metres (Photographs 15 to 19). Normally, the traps are set in a line parallel to the coast. The fishing spots are situated at distances varying between 100-500 metres from the shore. The baits commonly used are dried or decaying holothurians (Holothuria atra), pieces of crab (Portunus pelagicus) and pieces of starfish. The traps are set in the morning (between 6 and 9 am.) and removed for emptying the catches the next morning at about the same time. While pulling up the traps on the following day, iron hooks are tied to a rope and then flung to the particular spot to pull up the float. Once the float is pulled up in the boat, traps are pulled in, one by one, and the contents are emptied into the boat by unlacing one corner of the trap. Fresh bait is then introduced, the edge laced back in position, and the traps are again set under water at a different place. Normally, one

Photographs 15 - 19

Trap operations at Vedalai from the moment they are set,

till they are hauled up for

being brought ashore.

Photograph 15

Photograph 16

Photograph 17

Photograph 18

Photograph 19

set of traps are used only for about a fortnight, after which it is removed for mending and sun drying. This process makes them more durable. Each fisherman normally owns two sets of traps, to permit for replacement and continuous operation.

Operation of traps on rocky bottom

Fishermen operate the larger traps with one or more entrances on the rocky bottom off Munakkad in the Palk Bay mainly for Siganus spp. Other fishes such as Psammoperca waigiensis, Lethrinus spp., Lutianus spp., Epinephelus spp., Plectorhynchus spp. and Gerres spp. are also caught frequently in these traps. Unlike the one-entrance smaller traps operated on the sandy bottom, these traps are not operated in series but are left scattered about in nooks and crannies of the coral beds. The bait commonly used is jelly fish but occasionally clupeoid fishes and holothurians are also used. After introducing bait, the traps are weighted by means of stones and then one of the fishermen dives down to selected spots and leaves them there. No floats are attached to these traps. Next morning, the traps are located by the fishermen with great skill. The traps are replaced by others, for mending and drying. The depth at which these are operated varies from 2-4 metres and the fishing places are situated at distances varying between 500-800 metres from the shore.

Traps fishing operations are conducted by

about twelve fishermen at Vedalai. They own about 600 traps of all sizes and types; each fisherman owns about 50 traps. The boat or catamaran used in the fishery is jointly owned by two or three fishermen and these men operate their respective traps from a common boat; four or five boats are engaged in the fishery in and around Mandapam. Similarly, at Rameswaram on the Rameswaram Island, a few fishermen who possess larger 2-5 entrance traps, operate them in the coral reefs fringing the coast.

2. Shore seine ('Olai Valai')

This type of net brings in fairly good quantities of P. waigiensis during certain months. About half a dozen nets of this type are owned by the Mandapam fishermen. The 'Olai Valai' comprises three parts, viz., the net proper ('Madi' in Tamil), the two lateral extensions or wings of the net ('Marku' in Tamil), and the five coir ropes (with the 'Olai') attached to each wing of the net terminating in a single thick coir rope of each side. The net proper is conical, the cod end of which has a width of about 3 metres. As one approaches the mouth of the net, the width narrows down to about 2 metres. This part of the net again widens out towards the two wings and at the mouth of the net, the width again approximates 3 metres. The head rope of the mouth and the wings are buoyed up by means of floats such as dried coconuts and the foot rope is weighted by means of stone or coral pieces, so that, the

gape of the mouth is kept as wide open as possible. Each of the two wings of the net has a length of about 680 metres and at the widest part, where the two wings of the net diverge most, the width is about 125 metres.

The cod end of the net has the smallest mesh and the mesh size increases towards the mouth of the net. Of the five coir ropes attached to each wing, one is attached to the head rope and the other to the foot rope of the wing of the net; the other three ropes are attached at equidistant points between these two ropes. All these coir ropes have the 'Olai' or dried palm leaves inserted in them, the distance between any two leaves being about 18 cm. At the other end, these five ropes meet the main coir rope and 'Olai' are also inserted in this thick coir rope up to a certain stretch only. Beyond this point, the main coir rope is devoid of any leaves.

One end of the coir rope is left on the shore in the custody of a few men and the net along with the other end of the coir rope is staked in a boat. The boat is launched out in the sea to a distance of about 200-300 metres, taking a perpendicular course all the time. The net is shot on sighting shoals of fish and the other end is quickly brought to the shore. The net is then dragged at the two ends to land the bag of the net (Photographs 20 to 22). The whole operation takes about 3 hours. In all, about twleve fishermen operate a net. The net is always dragged on a sandy bottom.

Photograph 20. The shore seine, 'Olai Valai' in operation.

Photograph 21. The 'Olai Valai' just hauled up.

Photograph 22. A portion of the 'Olai Valai' catch.

Photograph 20

Photograph 21

Photograph 22

The catches of 'Olai Valai' comprise mostly the same species of fish found in the trap catches except that larger individuals of Epinephelus spp., Lethrinus spp., and Psammoperca waigiensis are also caught. Other fishes such as Tylosurus spp., Hemirhamphus spp., Sphyraena spp., etc. are also met with in the 'Olai Valai' catches.

3. Bottom-set gill net ('Kannikka Valai' or 'Senganni Valai')

The gill net known locally as the 'Kannikka Valai' or 'Senganni Valai' is used at Devipatnam and Tondi.

The net essentially consists of two parts - the upper piece made of thinner thread (No.10) having a width of a little over half a metre (about 55cm.) and of 40 mm. mesh (stretched) and the lower piece made of thicker thread having a width of about 3-5 cm. and of 10 mm. mesh. Each net has a length of about 23-45 metres and is provided with wooden floats, the average distance between any two floats being about 45 cm. The net is weighted down by the lower piece of thick netting.

At Devipatnam, four or five fishermen (each fisherman owns five or six nets) proceed to the fishing spot in the early hours of the morning (between 2 and 4 a.m.) in a boat; the fishing spot is located at a distance of about 8-13 kilometres from the shore and at a depth of about 6-8 metres. After reaching the particular spot, each fisherman shoots his nets and the boat drifts with the current till the net is hauled up at about 6 a.m. This net brings in

heavy catches of P. waigiensis frequently at Devipatnam. About twenty-five fishermen are engaged in gill net operations at Devipatnam.

In this net, the fish get entangled either by the opercular or preopercular bone. The small piece of thicker net at the base serves mainly two functions - to keep the upper piece of the net in stretched condition by its own weight and to disturb the fish at the bottom. The latter function is performed by the fish already captured in the upper piece of the net; these fish cause the lower net to be moved about by their own wriggling movements, which in turn cause the disturbed fish from below the net to move up and to be consequently caught in the upper piece of net.

4. Hooks & lines ('Thoondi')

This is the principal gear used at Devipatnam. Most of the landings at Devipatnam are accounted for by hooks & lines, locally called 'Thoondi'. Hooks of the commercial sizes 12, 13, 14 and 15 are commonly used, number 12 being the largest and 15 the smallest. Each fisherman engaged in this fishery owns several lines, each varying in length from 500 to about 2000 metres; the average distance between any two hooks is about 2 metres, so that, a line of 2000 metres has 1000 hooks. Thread No.20 is used for preparing the lines. Five of these threads are twisted and three such twisted threads make one compact thread having

a diameter of 1 mm.

The line is set at about 5 a.m. at a fishing spot which is about 8-13 kilometres away from the shore; the line is suspended above the sea floor by means of long ropes having dried coconuts with husk as floats. The depth at the fishing spot varies between 6-8 metres and the length of the rope bearing the floats above and the line with the hooks below varies between 3-4 metres. Fishermen first collect the bait items such as fingerlings of teleostean fishes, viz., Platycephalus spp., Caranx spp., Siganus spp., Therapon spp., etc. and crabs, prawns and squids by means of small hand nets (known as 'Raanji Valai' locally) between 1 and 2 a.m. in the coastal waters. After collection of bait, two or three fishermen get into a canoe with their respective lines, and while on their way to the fishing spot they bait the hooks, so that, the lines can be shot immediately on reaching the particular spot. The species takes the bait quickly and by about 7 a.m., the lines are hauled into the canoe. About ten canoes are used and thirty fishermen are dependent for their livelihood on the hook & line fishery. An average earning of about Rs.5.00 per day of fishing by each boat with three fishermen on board amounts to about Rs.1.65 per head.

Catch data

Average annual landings

The average annual landings for the period-

1954-1957 at Vedalai and Munakkad, Devipatnam and Tondi are given below:

Centre	Annual landings (kg.)
Vedalai and Munakkad ...	544.8
Devipatnam	5977.8
Tondi	4086.0
Total	10608.6

The catches were maximum (5977.8 kg.) at Devipatnam followed by Tondi and Vedalai and Munakkad. The huge landings at Devipatnam are evidently due to the more or less constant operations of hooks & lines, which is not the case elsewhere.

Percentage catch of P. waigiensis per trap per month

In order to study the total catch and the percentage catch of P. waigiensis month to month, total weight of 'all fish' and that of P. waigiensis in a set of 50 one-entrance traps were noted during bi-weekly visits to Vedalai and Munakkad during the period June 1956-March 1957. The average weights of the above per trap per month were then calculated. The details along with the percentage composition of P. waigiensis by weight are shown in Table XLIX. It may be seen from the table that the total

catch per trap was maximum in September 1956 and minimum in March 1957 at Vedalai. The percentage composition of P. waigiensis was highest in July 1956 at Munakkad and lowest in November 1956 at Vedalai. Although the data for Munakkad is available only for two months, the percentage composition of P. waigiensis at this centre generally seems to be higher than that at Vedalai.

TABLE XLIX

Monthly variations of total catch and P. waigiensis per trap (June 1956 - March 1957)

Year and month	Centre	Total catch per trap (kg.)	Catch of P. waigiensis per trap (kg.)	Percentage composition of P. waigiensis
1956				
June	Munakkad	0.1623	0.0347	21.61
July	"	0.0936	0.0321	34.04
August		No data		
September	Vedalai	0.3360	0.0600	17.86
October	"	0.0874	0.0083	9.50
November	"	0.1093	0.0071	6.95
December	"	0.0659	0.0059	8.95
1957				
January	"	0.0600	0.0044	7.33
February	"	0.0363	0.0036	10.00
March	"	0.0250	0.0038	15.20

CHAPTER 9

AGE-GROUP COMPOSITION OF THE COMMERCIAL CATCHES AND ESTIMATION OF VITAL STATISTICS

According to conventional procedure adopted in fishery biological studies, fish below age 1 are termed the O-group, those between ages 1 and 2 are termed the I-group and those between ages 2 and 3 are termed the II-group and so on. Five age-groups are recognisable in the fishery, viz., O-group, I-group, II-group, III-group and IV-group. Based on estimated values of the size of the fish at successive ages calculated from the von Bertalanffy equation, the month-wise fluctuations in the percentage occurrence of various age-groups in the fishery at Vedalai and Munakkad, Devipatnam and Tondi are presented in Tables L, LI and LII.

Age-group composition (month-wise) of the commercial catches Vedalai and Munakkad

As could be seen from Table L, the O-group ranged from a minimum of 0.69 per cent in November 1954 to a maximum of 80.14 per cent in August 1957 during the period July 1954-October 1957. In the month of January 1957, this group was totally absent from the fishery.

The I-group was the mainstay of the fishery, as could be seen from percentage values through different months. This group was minimum (17.94 per cent) in August 1957 and maximum (99.15 per cent) in January 1957. In

TABLE L

Age-group composition (month-wise) of the commercial catches of P. waigiensis at Vedalai and Munakkad (July 1954 - October 1957)

Year and month	AGE-GROUPS									
	0-group		I-group		II-group		III-group		IV-group	
	No.	%	No.	%	No.	%	No.	%	No.	%
1954										
July	21	3.48	556	92.21	26	4.31	--	--	--	--
August	349	42.14	448	54.11	30	3.63	1	0.12	--	--
September	133	25.19	318	60.24	52	9.82	21	3.99	4	0.76
October	79	9.69	700	85.89	34	4.17	2	0.25	--	--
November	3	0.69	389	89.63	34	7.83	7	1.62	1	0.23
December	3	0.83	331	92.20	25	6.97	--	--	--	--
1955										
January	No data									
February	No data									
March	No data									
April	24	35.81	27	40.29	16	23.90	--	--	--	--
May	2	1.98	89	88.11	10	9.91	--	--	--	--
June	54	5.71	813	86.03	76	8.04	2	0.22	--	--
July	18	4.20	371	86.48	34	7.92	6	1.40	--	--
August	18	6.91	201	75.86	37	14.03	6	2.37	2	0.83
September	6	5.09	110	93.22	2	1.69	--	--	--	--
October	12	4.65	233	89.97	12	4.64	2	0.74	--	--
November	45	19.65	161	70.30	21	9.17	1	0.44	1	0.44
December	141	12.81	918	83.38	40	3.63	2	0.18	--	--

Continued

TABLE I (Continued)

Age-group composition (month-wise) of the commercial catches of P. waigiensis at Vedalai and Munakkad (July 1954 - October 1957)

1956										
January	7	4.43	130	82.27	18	11.40	3	1.90	--	--
February	25	9.23	235	86.72	10	0.37	1	3.68	--	--
March	20	12.90	124	80.00	8	5.16	3	1.94	--	--
April	65	22.80	213	74.74	6	2.11	1	0.35	--	--
May	152	28.58	362	68.04	18	3.38	--	--	--	--
June	77	8.91	749	86.69	38	4.40	--	--	--	--
July	30	8.67	312	90.17	4	1.16	--	--	--	--
August	No data									
September	6	10.17	50	84.75	3	5.08	--	--	--	--
October	12	4.40	258	94.50	3	1.10	--	--	--	--
November	27	4.19	604	93.64	14	2.17	--	--	--	--
December	10	2.37	386	91.47	22	5.21	3	0.71	1	0.24
1957										
January	--	--	117	99.15	1	0.85	--	--	--	--
February	7	5.37	115	88.46	8	6.17	--	--	--	--
March	8	6.96	98	85.22	9	7.82	--	--	--	--
April	No data									
May	9	12.33	62	84.93	2	2.74	--	--	--	--
June	No data									
July	74	77.08	18	18.75	3	3.13	1	1.04	--	--
August	125	80.14	28	17.94	3	1.92	--	--	--	--
September	11	17.74	48	77.42	3	4.84	--	--	--	--
October	1	4.36	20	86.95	2	8.69	--	--	--	--

most of the months, this group constituted over 50.00 per cent of the total catch; the only months when this group constituted less than 50.00 per cent of the total catch being April 1955 (40.29 per cent) and July (18.75 per cent) and August 1957 (17.94 per cent).

The II-group was present to a lesser extent in the fishery throughout the period of observation and ranged from a minimum of 0.37 per cent in February 1956 to a maximum of 23.90 per cent in April 1955. During the other months (except August 1955 and January 1956 when the II-group formed 14.03 per cent and 11.40 per cent respectively), this group occurred to the extent of less than 10.00 per cent of the catch.

The III-group occurred only during 16 months of the entire period of observation. The minimum of 0.12 per cent was recorded in August 1 and the maximum of 3.99 per cent was recorded in September 1954.

The IV-group occurred only during 5 months of the entire period of observation, the percentage values during September and November 1954, August and November 1955 and December 1956 being 0.76, 0.23, 0.83, 0.44 and 0.24 respectively.

Devipatnam

As could be seen from Table LI, the O-group ranged from a minimum of 1.08 per cent in June

TABLE LI

Age-group composition (month-wise) of the commercial catches of P. waigiensis at Devipatnam (October 1954 - April 1956)

Year and month	AGE-GROUPS									
	0-group		I-group		II-group		III-group		IV-group	
	No.	%	No.	%	No.	%	No.	%	No.	%
1954										
October	4	1.28	282	90.67	21	6.77	4	1.28	--	--
November	--	--	31	79.49	6	15.38	2	5.13	--	--
December	No data									
1955										
January	No data									
February	No data									
March	No data									
April	5	1.85	222	82.22	39	14.45	2	0.74	2	0.74
May	26	2.26	914	79.34	196	17.01	13	1.13	3	0.26
June	16	1.08	1321	89.38	130	8.79	9	0.61	2	0.14
July	63	2.85	2064	93.36	80	3.61	3	0.14	1	0.04
August	40	1.76	2151	94.77	75	3.30	3	0.13	1	0.04
September	--	--	1179	97.69	25	2.07	3	0.24	--	--
October	--	--	1451	95.20	71	4.67	2	0.13	--	--
November	--	--	890	81.65	190	17.43	9	0.83	1	0.09
December	30	4.38	311	45.40	289	42.19	48	7.01	7	1.02
1956										
January	11	2.21	378	75.91	102	20.48	7	1.40	--	--
February	77	19.64	245	62.50	63	16.07	7	1.79	--	--
March	38	26.39	63	43.75	35	24.30	6	4.17	2	1.39
April	36	18.09	93	46.74	54	27.13	13	6.53	3	1.51

1955 to a maximum of 26.39 per cent in March 1956 during the period October 1954-April 1956. This group was not represented in the fishery during November 1954 and September to November 1955. The High values were met with only during February to April 1956.

The I-group constituted over 50 per cent of the catch during all but three months, viz., December 1955 and March and April 1956, the percentage values in these months being 45.40, 43.75 and 46.74 respectively. The minimum value was recorded in March 1956 (43.75 per cent) and the maximum value in September 1955 (97.69 per cent). As at Vedalai and Munakkad, this group was the mainstay of the fishery at Devipatnam during the period of observation.

The II-group occurred in the catches during all the 15 months. The minimum (2.07 per cent) was in September and the maximum (42.19 per cent) in December 1955.

The III-group was represented in the catches during all the 15 months. This group ranged from a minimum of 0.13 per cent in August and October to a maximum of 7.01 per cent in December 1955.

The IV-group formed an infinitesimal part of the catches at Devipatnam as could be seen from the percentage values. The group was absent from the catches during the months of October and November 1954, September

and October 1955 and January and February 1956. The minimum of 0.04 per cent was noticed in July and August 1955 and the maximum of 0.51 per cent in April 1956.

Tondi

As could be seen from Table LII, the O-group occurred in the catches at Tondi during October and November 1955 and January, February, March and June 1956. The group formed a minimum of 1.54 per cent in November 1955 and a maximum of 47.54 per cent in March 1956.

The I-group formed the mainstay of the fishery at Tondi during the period of observation, as was the case at Vedalai and Munakkad and Devipatnam. It was minimum (44.26 per cent) in March 1956 and maximum (97.76 per cent) in November 1955, with intermediate values during the other four months.

The II-group was present at Tondi during all the six months of observation but formed a very small proportion of the catch. This group was minimum (0.70 per cent) in November 1955 and maximum (18.52 per cent) in June 1956.

The III-group was present only during three months - February, March and June 1956 forming 0.32, 1.65 and 2.31 per cent respectively.

TABLE LII

Age-group composition (month-wise) of the commercial catches of P. vaigiensis at Tondi (October 1955 - June 1956)

Year and month	AGE-GROUPS									
	O-group		I-group		II-group		III-group		IV-group	
	No.	%	No.	%	No.	%	No.	%	No.	%
1955										
October	55	15.71	282	80.58	13	3.71	--	--	--	--
November	11	1.54	697	97.76	5	0.70	--	--	--	--
December	No data									
1956										
January	149	43.95	174	51.33	16	4.72	--	---	--	--
February	121	39.16	151	48.87	34	11.00	1	0.32	2	0.65
March	58	47.54	54	44.26	8	6.55	2	1.65	--	--
April	No data									
May	No data									
June	22	10.18	147	68.06	40	18.52	5	2.31	2	0.93

The IV-group occurred only during February (0.65 per cent) and June 1956 (0.93 per cent).

Age-group composition (year-wise) of the commercial catches

Vedalai and Munakkad

If the age-group composition of the commercial catches at Vedalai and Munakkad during the four years 1954, 1955, 1956 and 1957 is studied from Table LIII, it would be seen that the I-group formed the mainstay of the fishery during the four years forming 76.87 per cent in 1954, 83.21 per cent in 1955, 85.36 per cent in 1956 and 65.46 per cent of the total catch in 1957. This group is followed in the order of abundance by the O-group and the II-group during the four years. The III-group and IV-group formed an insignificant part of the catch.

Devipatnam

The age-group composition of the commercial catches at Devipatnam, as seen in Table LIV, portrays almost the same picture except that the I-group instead of being followed by the O-group in the order of abundance is followed by the II-group. The I-group formed 89.43 per cent in 1954, 88.36 per cent in 1955 and 63.17 per cent of the total catch in 1956. The III-group and the IV-group occurred to a lesser extent in the catches.

Tondi

The age-group composition of the commercial

TABLE LIII

Age-group composition (year-wise) of the commercial catches of P. waigiensis at Vedalai and Munakkad
(1954- 1957)

Year	AGE-GROUPS									
	0-group		I-group		II-group		III-group		IV-group	
	No.	%	No.	%	No.	%	No.	%	No.	%
1954	588	16.48	2742	76.87	201	5.64	31	0.87	5	0.14
1955	320	9.40	2923	83.21	248	7.06	19	0.24	3	0.09
1956	431	10.75	3423	85.36	144	3.59	11	0.27	1	0.03
1957	235	30.40	506	65.46	31	4.01	1	0.13	--	--

TABLE LIV

Age-group composition (year-wise) of the commercial catches of
P. waigiensis at Devipatnam
(1954 - 1956)

Year	AGE-GROUPS									
	0-group		I-group		II-group		III-group		IV-group	
	No.	%	No.	%	No.	%	No.	%	No.	%
1954	4	1.14	313	89.43	27	7.71	6	1.72	--	--
1955	180	1.51	10503	88.36	1095	9.21	92	0.77	17	0.15
1956	162	13.14	779	63.17	254	20.60	33	2.68	5	0.41

catches at Tondi, as seen in Table LV, shows the preponderance of I-group in the catches during the years 1955 and 1956, when it occurred to the extent of 92.10 per cent and 53.34 per cent respectively. The I-group is followed by the O-group, which in turn is followed by the II-group. The IIIgroup and the IV-group did not occur in the catches at Tondi during 1955. During 1956, the two age-groups occurred to a negligible extent.

If the age-group composition at Vedalai and Munakkad, Devipatnam and Tondi is compared, it will be found that the fishery draws its main support from the I-group at all the three places during the periods of observation. Since the fish attains first maturity at an approximate size of 14-16 cm. when they are about a year old, the fishery may be said to operate on adults, most of which, would have spawned at least once. Since, the fishing methods are such that probably only a fringe of the total stock of P. waigiensis is exploited, it is unlikely that sufficient numbers of spawners will not be left behind to replenish the stock in future for the maintenance of the commercial fishery at its present stage.

Estimation of vital statistics

The age-group composition (year-wise) of the catches at Vedalai and Munakkad, Devipatnam and Tondi has been shown in Tables LIII, LIV and LV. Since, mainly one kind of gear, viz., traps were operated at Vedalai and

TABLE LV

Age-group composition (year-wise) of the commercial catches of
P. waigiensis at Tondi
(1955 - 1956)

Year	AGE-GROUPS									
	0-group		I-group		II-group		III-group		IV-group	
	No.	%	No.	%	No.	%	No.	%	No.	%
1955	66	6.21	979	92.10	18	1.69	--	--	--	--
1956	350	35.50	526	53.34	98	9.95	8	0.81	4	0.40

Munakkad, these data are further analysed for the estimation of vital statistics. Table LVI gives the number of each age-group of P. waigiensis landed in the area per 100 traps.

TABLE LVI

Number of P. waigiensis of each age-group landed at Vedalai and Munakkad per 100 traps (1954-1957)

Year	Age-groups				
	0	I	II	III	IV
1954	18.38	85.69	6.28	0.97	0.16
1955	14.95	136.59	11.59	0.89	0.14
1956	17.10	135.83	5.71	0.45	0.04
1957	58.75	126.50	7.75	0.25	--

Beverton and Holt (1957) have shown that if the number of fish of age t in any year is N_t and if the number of fish of age t + 1 next year is N_{t+1}, then $\log \frac{N_t}{N_{t+1}}$ will give an estimate of the total instantaneous mortality coefficient F + M between the age-group t and t + 1. Following this, the total mortality coefficients between the different age-groups were calculated for the different years and shown in Table LVII. Since the fish is recruited to the fishery after it has completed age 1, the 0-group was omitted from such calculations.

TABLE LVII

Apparent total mortality coefficients (F + M) for P. Waigiensis, derived from Table LVI

Year	Age-groups			
	I/II	II/III	III/IV	Average
1954	0.87	0.85	0.84	0.85
1955	1.38	1.41	1.34	1.38
1956	1.24	1.36	--	1.30
Average	1.16	1.21	1.09	1.18

It may be seen from the above table that in any one year the total mortality coefficient F + M from age-group I onwards remains remarkably constant. But the average values between different years seem to vary a good deal. Since only three years data are available, it is not possible to separate F and M by the regression method prescribed by Beverton and Holt. Since the fishery is restricted to the inshore waters and exploited by few traps only, and since the fishery is based on adults after they have attained maturity, it may be presumed that the component of fishing mortality is small. If this is so, the natural mortality is expected to be very high and since the species is short-lived, it is rational to exploit it further, without detriment to the fish stock.

SUMMARY

The common perch, Psammoperca waigiensis (Cuvier) supports a sustenance fishery at many localities along the coasts of Palk Bay and Gulf of Mannar. Although an important food fish, very little information was available on its biology and fishery. Hence, a comprehensive study was initiated and the results of the investigations spread over a period of four years from 1954 to 1958 are presented in this thesis. Certain corroboratory observations made during the subsequent years are also incorporated.

Meteorological, hydrographical and oceanographic conditions characteristic of the areas together with brief details of the fauna and flora are given.

A brief account of the systematics and distribution of the species is given.

The maturity stages are classified based on the macroscopic appearance of the gonads and microscopic study of the intra-ovarian eggs. A study of the gonads in each stage of maturity in relation to size of fish indicates that the fish attains first maturity at a size of 14 - 16 cm. when it is about a year old.

The determination of the spawning period and the frequency of spawning are based on the ova diameter studies, month-wise occurrence of fish in various stages of maturity, progression of the average size of the largest eggs,

fluctuations of the gonado-somatic index and relative condition factor of adult females, and occurrence of ripe and young fish. The fish seems to spawn throughout the year, except perhaps, during the months of May and June.

Studies on growth rate of gonads show that a linear relation exists between length of ovary/testis with increase in the length of fish, while the width of ovary/testis does not bear such a relationship with increase in the length of fish. Fecundity studies indicate that the number of eggs in a single batch range from about 16,600 to 242,000. The relationship between fecundity and (1) total length of fish, (2) weight of fish and (3) weight of ovary are given. The relationship between length of fish, weight of fish and weight of ovary are given. Sex ratio studies indicate that during the period of study, only at one centre (Tondi) in the Palk Bay, the ratio of males to females approximates the theoretically expected ratio. At the other two centres (Devipatnam and Munakkad) in the Palk Bay and at one centre (Vedalai) in the Gulf of Mannar, the females outnumber the males. At all the centres, the hypothesis of equality of sex distribution during different months could not be accepted and the sex ratio varied month to month.

Length-frequency studies show that the fish are recruited into the inshore fishery at about 16 cm. when they are about a year old. The fish attains a size of 16.5 cm. at the completion of one year and 23.2 cm. at the completion

of two years. It is inferred that only two age-groups are prominent in the fishery, the one-year-old fish being the mainstay of the fishery. These sizes are found to be in good agreement with mean sizes arrived at by a study of the otoliths, indicating thereby that the rings in otoliths are annual in nature. Back-calculations made from otolith readings indicate the mean sizes to be 14.50 cm., 20.77 cm., 26.16 cm. and 29.97 cm. from first to the fourth years respectively, showing a growth of 6.27 cm., 5.39 cm. and 3.81 cm. in the second, third and fourth years of life. The von Bertalanffy growth equation is found to describe the growth of the fish adequately, the estimated sizes being 13.74 cm., 21.79 cm., 26.82 cm. and 29.51 cm. from first to the fourth years respectively.

Studies on food and feeding habits indicate that in the Palk Bay, prawns constitute the major component of food; in the Gulf of Mannar, crabs constitute the major component of food. The greater incidence of prawns in the food of the fish in the Palk Bay is manifest in all fish. The greater incidence of crabs in the food of the fish in the Gulf of Mannar is manifest in fish above 15 cm. only; fish below 15 cm. feed more on prawns. The intensity of feeding is highest at Munakkad followed by Devipatnam, Tondi and Vedalai.

The length-weight relationship separately for the sexes is found to be:

Females: $W = 0.004372L^{3.3018}$

Males: $W = 0.007013L^{3.1771}$

The total length-standard length relationship is found to be:

$$Y = -0.7641 + 0.9202X$$

A morphometric study of fish from the Palk Bay and Gulf of Mannar indicates that, of the fifteen characters analysed, only four characters, viz., snout, head length, snout to pelvic fin and back depth show significant differences. A study of relative growth of body parts of the species indicates that the general trend of the rates of growth of all the characters in relation to total length is almost similar, snout to anal fin having the fastest rate of growth.

The fishery is mainly constituted by the I-group at the centres from which samples were drawn. The fishing methods are such that probably only a fringe of the total stock is exploited; it would appear that sufficient number of spawners are left behind to replenish the stock for the continuation of the commercial fishery at its present stage.

At Vedalai and Munakkad, the total mortality coefficient F + M from age-group I onwards remained remarkably constant during 1954, 1955 and 1956; but the average values between different years varied a good deal. Since the

fishery is restricted to the inshore waters and exploited by a small number of traps and since the fishery is based on adults after they have attained maturity, it is presumed that the component of fishing mortality is small. The natural mortality M is expected to be very high. Since the species appears to be shortlived, scope for further exploitation without detriment to fish stock is indicated.

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